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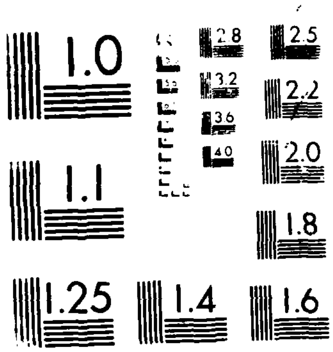
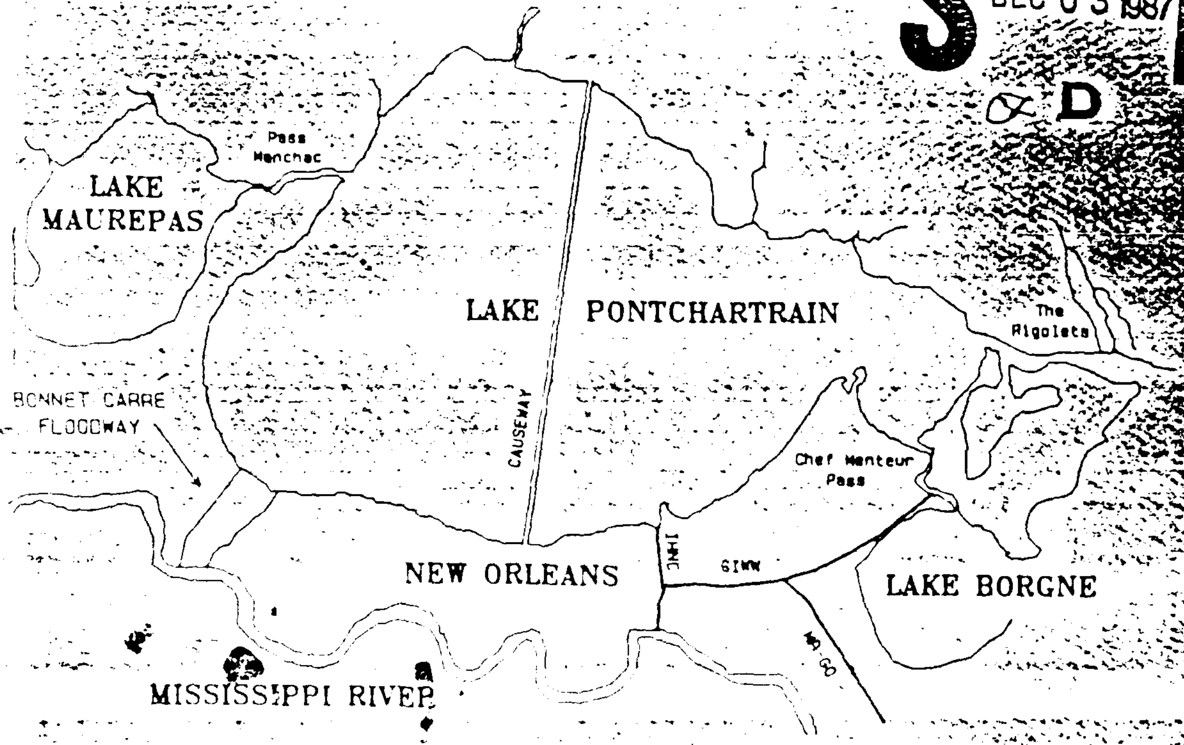


RESOLUTION TEST

STANDARDS

US Army Corps
of Engineers
New Orleans District

CLAM SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS, LOUISIANA



Volume 1

Final Environmental Impact Statement and Appendixes

November 1987

Unclassified

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Benthos	Fisheries	Social Impacts
Contaminants	Grassbeds	Turbidity
Cultural Resources	Lake Pontchartrain	Water Quality
Economic Environment	Sediments	Wildlife

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Clam shells (Rangia) have been harvested from Lakes Pontcahrtrain and Maurepas since 1933 by means of hydraulic dredges. The shells are used primarily in construction activities, but have a variety of other uses as well. There has been considerable controversy over the environmental impacts of shell dredging. This Final Environmental Impact Statement assesses the impacts of shell dredging in the lakes as permitted under 5-year permits issued in 1982 that will expire in December 1987. The document also addresses the impacts of applications for 10-year permit extensions that would allow shell (over)

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dredging to continue under the same conditions. These permit actions are being considered under Section 10 of the River and Harbor Act and Section 404 of the Clean Water Act. Numerous alternatives have been discussed and evaluated in the document.

A-1

FINAL ENVIRONMENTAL IMPACT STATEMENT

Clam Shell Dredging in Lakes Pontchartrain and Maurepas, Louisiana

The responsible lead agency is the U.S. Army Corps of Engineers, New Orleans District, New Orleans, Louisiana.

This FEIS assesses the impacts of clam shell dredging in Lakes Pontchartrain and Maurepas, Louisiana as permitted under 5-year permits issued in 1982 that will expire in December 1987. The document also assesses the impacts of proposed 10-year permit extensions that would allow shell dredging to continue under the same conditions. Applicants for the permits and extensions are Dravo Basic Materials Company, Inc. (formerly Radcliff Materials, Inc.), Pontchartrain Materials Corporation, and Louisiana Materials Company, Inc. These permit actions are being considered under the authority of Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act.

Abstract: Clam shells (Rangia) have been harvested from the lakes area since 1933 by means of hydraulic dredges. The shells are used primarily in construction activities, but have a variety of other uses as well. There has been considerable controversy over the environmental impacts of shell dredging. This FEIS assesses impacts to the lakes area with and without shell dredging under existing and future conditions. Numerous alternatives have been discussed and evaluated in the FEIS and two have been discussed in detail.

SEND YOUR COMMENTS TO THE DISTRICT ENGINEER BY: December 7, 1987

ADDRESS: District Engineer
U.S. Army Engineer District
P.O. Box 60267
New Orleans, Louisiana 70160-0267
ATTN: CELMN-PD-RE

If you require additional information, please call Ms. Laura J. Swilley at (504)862-2272.

S. SUMMARY

S.1. DESCRIPTION OF PROPOSED ACTION

The dredging of clam shells from the lakes area (Lakes Pontchartrain and Maurepas) began in the early 1930's. At that time, it was discovered that clam shells could be effectively harvested with sweeper-type dredges. The shells constitute a valuable mineral resource with a variety of uses. Their primary use is as a source of aggregate and calcium carbonate in construction and maintenance, but they are also used for non-constructive purposes such as lime manufacture, acid neutralization, water purification, petrochemical production, filter media, pharmaceuticals, poultry feed, and as cultch material for oyster production.

Over the years, the environmental impacts of shell dredging have been a source of increasing controversy, and many regulations and restrictions have been imposed by several regulatory agencies to lessen impacts. A complete list of these regulations is presented in Appendix B. Environmental Assessments addressing the impacts of shell dredging were prepared by the U.S. Army Corps of Engineers in 1982 and 1984. However, following extensive litigation, the Corps was ordered by the United States District Court, Eastern District of Louisiana, in April 1986, to prepare an Environmental Impact Statement (EIS) to further assess the impacts of the activity. This EIS assesses the impacts of clam shell dredging in Lakes Pontchartrain and Maurepas and has been prepared under the authority of Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act.

S.2. SUMMARY OF MAJOR ALTERNATIVES

During the scoping process, several generic alternatives were identified for consideration in this EIS. Based on this guidance, a

variety of specific alternatives were developed for consideration in this EIS. These alternatives are evaluated in Section 2 of the document. Alternatives examined include the following:

No Federal Action (Permit Denial)

Renew Permits With Existing Conditions (Applicant's Proposal)

Renew Permits With Additional Restrictions on:
- Areas available for dredging
- Dredging intensity
- Dredge discharge

Renew Permits With Reduced Restrictions on:
- Areas available for dredging
- Dredging intensity
- Dredge discharge

Based on a thorough analysis of the alternatives, it was determined that the following alternatives should be investigated in detail throughout the EIS:

Renew Permits With Existing Conditions

No Federal Action (Permit Denial)

The impacts of these alternatives on each of the significant resources/issues are discussed in Section 3 of the document.

S.3. SUMMARY OF ENVIRONMENTAL IMPACTS

S.3.1. **Summary of Endangered Species Assessment**

Based on correspondence with the U.S. Fish and Wildlife Service and National Marine Fisheries Service (NMFS), it was determined that the only species that may be potentially impacted by the proposed activity are the Kemp's (Atlantic) ridley sea turtle, Lepidochelys kempi, which is endangered, and the loggerhead sea turtle, Caretta caretta, which is threatened. A Biological Assessment of impacts to these species was prepared and forwarded to NMFS. The assessment is presented in Appendix A. The assessment concluded that the impacts of shell dredging

to these sea turtles is negligible. NMFS has reviewed the Biological Assessment and they concur with our findings.

S.3.2. Summary of Water Quality Impacts

It is well documented that shell dredging causes a temporary, localized increase in turbidity and levels of total suspended solids in the immediate vicinity of the operating dredge(s). Due to the size of Lake Pontchartrain, in addition to the fact that salinity levels in the lake are usually conducive to flocculation (formation of compound masses of particles) and rapid settling of suspended sediments, this localized and temporary turbidity is generally not considered significant. Turbidity impacts in Lake Maurepas, however, are much more severe. Lake Maurepas is only about one-sixth the size of Lake Pontchartrain. It also has more limited tidal exchange, very low salinities (nearly fresh), and averages only about 7 feet in depth. These factors, combined with possible differences in sediment composition and distribution, cause turbidity levels as a result of shell dredging to remain excessively high for long periods of time.

It is possible that shell dredging has contributed to the apparent long-term increase in turbidity in Lake Pontchartrain. It is reasonable to assume that the less consolidated sediments that persist for a period of time following dredging activities are more susceptible to resuspension by wave activity. However, since turbidity levels in the lake prior to the advent of shell dredging are unknown, and since many other factors have also contributed to increased turbidity, it is not possible to quantify the impact of shell dredging on long-term turbidity increases.

On the basis of field investigations and engineering analyses of Lake Pontchartrain shell dredging operations, it is generally concluded that the discharged slurry undergoes turbulent mixing in the upper water column where it is also dispersed by the propeller wash created by the

moving dredge. Upon the dissipation of the momentum imparted by the dredge, flocculation and gravity settling of the finer sediment particles begins, and all but a minor fraction of the sediments become deposited as a thin layer of fluid mud on the bottom soon thereafter.

The newly-deposited material is estimated to have an average thickness of less than one inch within a 50-foot wide zone along each side of the dredge path, diminishing to less than 0.1 inch at distances of 100 feet or more within one hour after dredging. Gravity, tidal currents and consolidation, and possibly one or more additional dredge passes over an area contribute to the continued vertical and lateral redistribution of the newly-deposited sediments.

With regard to contaminants, studies indicate that the highest levels of contaminants occur in nearshore sediments, particularly where outfall canals and tributaries enter the lakes. High levels of contaminants do not appear to be a problem in the open-lake areas. The higher levels of contaminants occur in areas where dredging is restricted, and problems related to release of contaminants from bottom sediments appear to be minimal. Additionally, studies conducted by the Louisiana Department of Environmental Quality indicate that contaminants released into the water column by shell dredging return to background levels in a very short period of time.

S.3.3. **Summary of Biological Impacts**

Shell dredging does not have a significant direct impact on the grassbeds in Lake Pontchartrain. The grassbeds are all located in nearshore areas, well within the one-mile boundary restricted from shell dredging activities. Based on the areal extent of the turbidity plume in the vicinity of operating dredges, this localized turbidity should exert negligible impacts on the grassbeds. It is believed that the apparent long-term increase in overall lakewide turbidity levels has adversely impacted the grassbeds. However, shell dredging is only one of a variety

of factors implicated in the increase in turbidity levels, and the contribution of shell dredging to the long-term increase is unknown. No grassbeds have been reported in Lake Maurepas.

The increase in turbidity in the immediate vicinity of operating dredges would temporarily decrease phytoplankton production. In Lake Pontchartrain, this temporary decrease in productivity is not considered significant. Even with all seven currently permitted dredges operating, only a very small percentage of the total area of the lake is affected by short-term turbidity at any given time. Impacts of the apparent long-term increase in lakewide turbidity on phytoplankton productivity are more difficult to assess. The impact of shell dredging on long-term turbidity increases in Lake Pontchartrain is unknown. Studies have shown that shell dredging in Lake Maurepas causes lakewide, persistent elevated levels of turbidity. Impacts of turbidity on phytoplankton production in that lake would be significant and much more severe than in Lake Pontchartrain.

Major changes in the benthic community of Lake Pontchartrain have taken place since the first studies were conducted in the 1950's, the most notable being the dramatic reduction in abundance of large Rangia in the open lake. Information presented in this EIS indicates that shell dredging has played a major role in the decline of large Rangia. The periodic disturbance of the bottom by shell dredging has also played a major role in other changes in the benthic community, including an apparent increase in the abundance of the two small hydrobiid gastropods (snails), Probythinella louisianae and Texadina sphinctostoma, as well as a variety of other opportunistic benthic organisms. However, there are no data to document that these changes have adversely impacted fish and wildlife resources or overall lakewide productivity. The majority of organisms that prey on Rangia prefer the smaller clams, which are still plentiful in the lake. Additionally, studies have shown that most of the demersal fish species in the lake are opportunistic feeders, consuming whatever benthic organisms are available.

The changes that have occurred in the benthic community began many years ago during the early years of shell dredging. Species abundance and composition undoubtedly experienced major changes due to direct disturbance of the bottom sediments and associated factors such as fluid mud and high concentrations of suspended sediments. It is likely that the benthic communities that exist in the lake today would change little as a result of shell dredging if dredging continues under existing conditions.

Studies regarding the fishery resources of the lakes have been reviewed in the EIS. The studies indicate there has been a decrease in abundance and frequency of occurrence of some demersal fish species since the 1950's, including sand seatrout, spot, hogchoker, and southern flounder. These species are known to utilize the open-lake habitats and several investigators have stated that the decline of these species may be due to stresses in the open-lake environment. Based on studies regarding the feeding habits of these species, there is no evidence that the changes in the benthic communities as a result of shell dredging has adversely impacted these species. The spot and hogchoker directly depend upon benthic organisms for their food source, but neither feed on large Rangia. The sand seatrout and southern flounder do not feed on benthic organisms direct'y associated with the sediments, and mollusks are rarely consumed by these species. Atlantic croaker, the second most dominant fish species in Lake Pontchartrain, directly utilizes benthic organisms as a food source, but has not demonstrated a noticeable decline in abundance or frequency of occurrence. Since a very small percentage of Lake Pontchartrain is affected by elevated short-term turbidity at any given time, fishery impacts related to short-term turbidity are not considered significant. In Lake Maurepas, where it has been shown that shell dredging causes lakewide, persistent elevated levels of turbidity, impacts to fishery resources as a result of turbidity could be significant. As discussed in section S.3.2, shell dredging may have also contributed to long-term turbidity increases in Lake Pontchartrain. However, data indicate that the fish community in the lakes is relatively healthy when compared to other Louisiana estuaries.

S.3.4. **Summary of Cultural Impacts**

There are no known cultural resources eligible for listing or listed on the National Register of Historic Places located in the permit area. Any Department of the Army Permits, if issued or extended, would contain special and general conditions requiring the permittee to notify the Corps if any previously unknown historic or archeological remains are discovered while accomplishing the activity authorized by the permit. The Corps would then initiate the Federal and state coordination required by 33 CFR Part 325, Processing of Department of the Army Permits; Procedures for the Protection of Cultural Resources. Extensive shell dredging has occurred in the lake since 1933, and there are no reports of shipwrecks being encountered.

S.3.5. **Summary of Recreational Impacts**

Due to the areal restrictions around the shoreline of Lake Pontchartrain, it is unlikely that recreational activities along the shores would be significantly impacted. The primary impacts of shell dredging on recreation would arise when dredges are working in the lake in areas where boaters are attempting to fish or shrimp. The zoning restrictions imposed upon the shell dredgers in Lake Pontchartrain are designed to reduce conflicts among user groups. Due to the great size of the lake, only a small percentage is affected by shell dredging at any given time. However, it is conceivable that the dredges could be working in areas deemed highly desirable for these recreational activities and the recreationists would be forced to move to another area. In Lake Maurepas, where shell dredging has been shown to cause very high, lakewide levels of turbidity, recreational fishing could be significantly impacted.

S.3.6. **Summary of Economic Impacts**

For more than 50 years, clam shells have been harvested from the lakes area and used primarily as aggregate and a basic building material. The mineral content and texture of this important natural resource have also made shells valuable in the production of many commodities, including petroleum, cement, lime, animal feed, glass, various chemicals, products used in acid neutralization, the reduction of smoke emission, and as oyster cultch. Recent estimates of average prices and production indicate that the gross value of shells harvested from the lakes area is about $34 million annually. Permit applicants estimate that if demand and production continues at recent rates, the amount of resource remaining in Lake Pontchartrain could last as much as 17 years, while the volume remaining in Lake Maurepas could last about 8 years, for a total of 25 years. The physical properties of shell make it a unique material for road construction in Louisiana's coastal lowlands, where the soil tends to be moist and limestone not immediately available. The shell producing companies provide local employment and income, particularly significant due to the area's recent economic downturn. Royalties and severance taxes collected by the state are used to provide public facilities and services. Permit denial would result in the loss of a large portion of these favorable economic impacts, with a more severe effect than the gradual depletion of the resource. Replacing shell with a more costly alternative material could only partially offset adverse impacts to the economy.

While the economic value of shell has been largely undisputed, there has been growing concern over the effects shell dredging may have on other activities in the lakes, including commercial and recreational fishing. In 1985, commercial landings of finfish and shellfish from the Lakes Maurepas, Pontchartrain, and Borgne area were valued at about $7.4 million. The gross value of the blue crab catch, which has been the major commercial fishery in Lake Pontchartrain, accounted for $946 thousand. These figures, however, may not reflect the full

significance that the demand for seafood has on the local economy. Since the lakes are located near heavily urbanized areas, much of the harvested seafood is sold directly to consumers and is not statistically recorded. The recreational harvest of seafood is not included in landings data. Additionally, many finfish and shellfish species that utilize the lakes as a nursery area are eventually harvested in other areas such as Chandeleur and Mississippi Sounds.

S.3.7. **Summary of Social Impacts**

Social considerations other than those directly related to economics include esthetic values, archeological and cultural resources, community growth, community cohesion, noise, public safety, and displacement of people. The shoreline restrictions imposed upon the shell dredgers in Lake Pontchartrain make impacts to esthetic values relatively minor. High levels of turbidity in Lake Maurepas due to shell dredging could adversely impact esthetic values. Due to the shoreline restrictions, noise impacts would be minor in both lakes. Companies involved in shell dredging are subject to all safety standards set by the Federal Occupational Safety and Health Administration (MSHA), including those for noise impacts. Careful administration and operation of the Collision Avoidance Warning System (CAWS) should reduce the risk of vessels striking the Causeway and minimize the impacts to public safety. If permits are denied and shell dredging operations are abruptly discontinued, the loss of employment and income that would result could require people to relocate, resulting in the separation of extended families and displacement of people from their community. The potential for this seems high given the current level of unemployment in the region. Permitting shell dredging as currently authorized would help sustain the current community structure and have a less severe impact on displacements, even though there are indications that the gradual decline of shell resources would eventually require the restructuring of industries which supply aggregate and calcium-carbonate in the area. Environmental concerns over the pattern of change in Lakes Maurepas and

Pontchartrain have often focused on the effects which shell dredging may have on the lakes ecosystem. Completion of a thorough environmental review should reduce the potential for conflict between interested parties.

S.4. Summary of Judicial Requirements

This EIS assesses the impacts of shell dredging on all of the significant resources/issues surfaced during litigation as well during the scoping process. In the April 1986 court opinion, the United States District Judge ordered that the Lakes Area EIS(s) shall at a minimum analyze the possible impacts of shell dredging on several areas of concern. These concerns are listed below accompanied by a description of where these items are discussed in the EIS and appendixes.

a. Ecological health of Lake Pontchartrain - This is a very broad area of concern and encompasses a variety of physical, chemical, and biological factors that have been discussed at length throughout the EIS and appendixes. Section 3 of this EIS, in particular, discusses existing conditions and impacts of shell dredging on areas of concern including water quality (Section 3.4.2.1), sediment quality/contaminants (Section 3.4.2.2), physical characteristics of sediments (Section 3.4.2.3), grassbeds (Section 3.5.1.1), phytoplankton (Section 3.5.1.2), benthos (Section 3.5.2.1), fisheries (Section 3.5.2.2), wildlife (Section 3.5.2.3), and endangered and threatened species (Section 3.5.2.4).

Appendixes A, C, and D provide additional technical information regarding these areas of concern.

b. Benthic fauna - Discussions regarding benthic fauna and the impacts of shell dredging on benthos constitute an substantial component of this document. Section 3.5.2.1 of this EIS discusses at length the benthic communities in the Lakes Area and the impacts of shell dredging on these communities. Appendix D provides additional technical information regarding benthic fauna.

c. Vegetable material on the bottom - Vegetable material on the bottom may include submerged aquatic vegetation (grassbeds) as well as the dead bodies of phytoplankters that fall to the bottom and contribute to the detrital layer. Grassbeds are discussed in Section 3.5.1.1 of the EIS and in Appendix D. Phytoplankton is discussed in Section 3.5.1.2 of the EIS and in Appendix D.

d. Turbidity - Turbidity has been one of the primary areas of concern in relation to shell dredging. Turbidity in Lakes Pontchartrain and Maurepas and the impacts of shell dredging on turbidity have been discussed in this EIS in Sections 3.4.2.1 (Water Quality) and 3.4.2.3 (Sediments - Physical Characteristics), as well as in Appendix C. Discussions of the impacts of turbidity on biological resources have been discussed in Sections 3.5.2.2 (Fisheries). Additional technical information regarding impacts of turbidity on biological resources is presented in Appendix D.

e. Water quality - Section 3.4.2.1 (Water Quality) of this EIS discusses a variety of physical and chemical water quality parameters including salinity, turbidity, dissolved oxygen, temperature, biochemical oxygen demand, total organic carbon, pH, alkalinity, total suspended solids, true color, and nutrients. Section 3.4.2.2 (Sediment Quality - Contaminants) discusses the occurrence of a variety of contaminants in the sediments and the impacts of shell dredging on the potential release of contaminants from the sediments into the water column. Additional technical information regarding water quality is presented in Appendix C and Section 3.8 (Cumulative Impacts) of this EIS.

f. Fossil shell depletion - The depletion of fossil (dead) shells is discussed in this EIS in Sections 3.5.2.1 (Benthos), 3.6 (Economic Environment), and 3.7 (Social Environment). It is estimated that reserves of fossil shells in Lake Pontchartrain are sufficient to sustain dredging at current levels for about 17 years and those in Lake Maurepas for about 8 years. Depending upon whether or not Lake Maurepas is reopened for dredging, the depletion of fossil shells would take from 17 to 25 years. The depletion of fossil shells and shell hash may have

reduced the stability of the lake bottom and has possibly caused some changes in the composition of benthic fauna. The most notable change in benthos has been the dramatic reduction of large, live Rangia in the open lake. Although it has been proposed that the larger clams may sink into the less stable sediments and die, the most probable cause for this reduction is that the frequency of disturbance by dredging precludes establishment of widespread populations of large clams.

From a socioeconomic standpoint, the depletion of fossil shells would cause significant impacts due to the gradual decline and ultimate cessation of the shell dredging industry (see Sections 3.6 and 3.7).

g. Long-term pollution of the lake - It is well documented that a variety of pollutants enter the Lakes Area from numerous sources and have for many years. Section 3.8 (Cumulative Impacts) of this EIS discusses some of these sources including sewage introduced into the lakes (Section 3.8.1), urban and agricultural runoff (Section 3.8.2), pollution from outboard motors (Section 3.8.4), and operation of the Bonnet Carre' Spillway (Section 3.8.5). With regard to shell dredging, Section 3.4.2.2 discusses contaminants that occur in lake sediments and the potential for release of these contaminants into the water column by shell dredging activities. Section 3.4.2.3 and other areas of the document discuss long-term increases in turbidity and suspended sediments caused by shell dredging, shrimping, and other factors.

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1. PURPOSE AND NEED FOR PROPOSED ACTION

1.1. STATEMENT OF PURPOSE AND NEED

With regard to private need, the applicants need a permit for the proposed activity in order to harvest clam shells and continue to function as a viable industry. From the public perspective, clam shells have a variety of commercial and industrial uses. Their primary use is in general construction and maintenance. They are used to construct roadways, parking lots, drill pads, and levees and are also used in the production of cement. Clam shells have certain properties that make them desirable as a base material for construction. The individual laminated particles are very strong and have interlocking qualities. The light bulk weight of clam shell, along with the interlocking properties, make them a desirable aggregate for construction of embankments, roads, foundations, work platforms, and underwater mats for drilling platforms. These uses constitute about 80 percent of the total shell utilization. The shells are also used for non-constructive purposes including lime manufacture, acid neutralization, water purification, petrochemical production, filter media to remove sulfur dioxide from power plant smoke stack emissions, pharmaceuticals, and poultry feed. Additionally, clam shells are used as cultch material to provide suitable substrate for oyster production. Since 1966, over 800 barges of shells have been deposited on state waterbottoms to enhance oyster production.

The shell dredging industry provides direct and indirect employment opportunities and also generates money for the State of Louisiana in the form of royalties and taxes.

1.2. HISTORY OF SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS

Lakes Pontchartrain and Maurepas are shown in Figure 1. In the early 1930's, it was discovered that sweeper-type dredges could harvest commercial quantities of clam shells from the bottom of Lake Pontchartrain. The harvested shells consist primarily of fossil shells

of the clam Rangia cuneata. The actual operation of these dredges is described in the next section.

The first permits and leases in the area are dated 1933 and 1934. Over the years, many different companies have operated dredges in the lakes. Between 1944 and 1959, as many as 15 individual operators dredged shells from the area. At present, three companies have exclusive leases from the Louisiana Department of Wildlife and Fisheries and are operating under approved permits from the Corps and several state agencies to dredge in Lake Pontchartrain. In March 1987, a state court declared all shell dredging leases invalid because they were executed in violation of several state statutes. However, the Corps is proceeding with completion of the shell dredging EIS's since it is obliged to do so by Federal court order. Shell dredging in Lake Pontchartrain has been essentially continuous since 1934.

Dredging in Lake Maurepas began again in 1983 after about a 15 year break. However, dredging in Lake Maurepas is presently prohibited by the Louisiana Department of Environmental Quality until it can be demonstrated that the shells can be harvested without violating state water quality standards.

The volume of clam shells harvested has varied considerably over the years (Figure 2), but has generally followed an upward trend until the mid-1970's. In the late 1930's, average annual harvest was only about 200,000 cubic yards per year. In the 1960's, harvests ranged from about 3 to 5 million cubic yards per year. Production peaked about 1975 with a harvest of 7.4 million cubic yards. The average annual harvest from 1975 to 1985 was about 5 million cubic yards. However, there was a steady downward trend during this 10 year period from about 7.4 million cubic yards in 1975 to 2.9 million cubic yards in 1985.

The shell dredging industry in the lakes is regulated by permits from the U.S. Army Corps of Engineers and the Louisiana Department of Natural Resources (DNR), leases from the Louisiana Department of Wildlife and Fisheries (LDWF), and water quality certificates from the Louisiana

Department of Environmental Quality (DEQ). A complete list of regulations and restrictions is presented in Appendix B.

1.3. DESCRIPTION OF SHELL DREDGING TECHNIQUES

There are currently seven dredges licensed to operate in the Lake Pontchartrain area. Specifications for these dredges are contained in engineering reports prepared for the three shell dredging companies in 1984 and 1985. Steimle and Associates, Inc. completed a report for Louisiana Materials Co., Inc. in January 1985, T. Baker Smith & Son, Inc. completed a report for Radcliff Materials, Inc. in December 1984, and Pontchartrain Materials Corporation completed a report in December 1984. Dredge specifications are also provided in the DNR permits. Although there are slight differences in the various dredges, all work on the same basic principle. A diagram of a typical sweeper-type dredge used for harvesting clam shells from Lake Pontchartrain is presented in figure 3. The dredges are either self-propelled or pushed by tugboat and move in a circular pattern at an average speed of about 1.92, or roughly 2.0, miles per hour (Steimle and Associates, 1985). They are equipped with a suction device known as a "fishmouth" similar to the head of a vacuum cleaner. The fishmouth is either pushed or pulled through the upper 20-30 inches of sediments. A typical trench cut by the fishmouth is about 4 to 6 feet wide and about 2 to 3 feet deep (GSRI, 1974). A thin layer of sediment deposition as a result of dredging activities occurs along the dredge path. This layer spreads in response to bottom currents until its density is sufficient to resist further movement.

Large pumps aboard the dredge create suction which draws a matrix of mud, shells, and water to an onboard processing system which separates the shells from other materials. The separation process consists of screening, sorting, and washing. Once the shell is removed, it is loaded by conveyors onto a barge which is lashed to the side of the dredge.

The separated sediments and water are discharged back into the lake by gravity flow. All of the water used in the separation and washing process is ambient water from the lake. Discharge of the slurry causes turbidity in the vicinity of the dredges.

2. ALTERNATIVES

2.1. INTRODUCTION

This section discusses alternatives addressed in this EIS. The alternatives include those identified through the scoping process. This section describes the major categories of alternatives and the rationale for their development. Some alternatives addressed in this section were eliminated from further study. Others were retained for further analysis throughout the entire EIS.

Shell dredging has taken place in the lakes area since about 1933. Through the years, many regulations and restrictions have evolved. As discussed in Section 1.2., the industry is regulated by several state and Federal agencies. The regulations have been developed through coordination among all parties involved. These factors play an important role in scoping the extent and magnitude of alternatives considered in this EIS.

2.2. DESCRIPTION OF ALTERNATIVES

2.2.1. **No Federal Action (Permit Denial)**

This alternative assumes that the permit(s) would be denied and all shell dredging activities would cease. A No Action alternative is always considered in an EIS. As part of the analysis under this alternative, other materials which could be used as an alternative to shells for their various important uses are investigated. Alternative materials identified by the public during the EIS process include limestone, gypsum waste, spent bauxite, and sand. The No Action alternative is considered in detail and retained for analysis throughout the EIS.

2.2.1.1. Alternative Materials

Thirteen materials that may be potential substitutes for shells were investigated. These materials include: asphalt concrete, clay, concrete, florogypsum, geotextile, gravel, limestone, phosphogypsum, recycled concrete, sand, scoria, shell, spent bauxite, and steel slag. The suitability of these alternative materials for current and potential engineering uses is displayed in Table 1. The materials are listed alphabetically and are not ranked in any way on the table. All of these materials have certain limitations. For many of them, uncertainties regarding their suitability exist and exhaustive testing and research are needed. As availability of other, more suitable, resources is diminished, it is likely that more studies on some of these other materials will be performed. However, such studies are beyond the scope of this document.

Asphalt concrete is a mixture usually composed of asphalt, mineral filler, fine aggregate, and coarse aggregate. It is used primarily in thin layers for road surfacing and as a base course for roads. If used as dolphin fill, it should only be placed above water. Costly compaction methods would probably be required due to the confined space in the dolphin. The lower portion of the dolphin would have to be filled with another material so that a strong mass was formed.

Clay is used in many locations for road embankment construction, except in coastal areas where shell is less expensive to ship, provides lighter loads on the foundation, is a stronger material, is more stable, and generally provides for use of less materials. Clay is a proven and accepted construction material in appropriate situations.

Concrete is composed of cement, aggregate, water and perhaps admixtures. It is a proven and accepted construction material in appropriate situations. Its use as dolphin fill would be restricted based on the bearing capacity of the foundation, which is poor in most Louisiana coastal areas.

TABLE 1

Possible Shell Substitutes
(U S Army Corps of Engineers)

Material	Estimated Bulk Density (lbs/ft3) MIN	MAX	Base[1] Course	Bedding	Concrete Aggregates	Road Surfacing	Dike[1] Cores	Dolphin[1] Fill	Filter	Pervious[1] Backfill	Subbase[1]	Surcharge
			Current and Potential Uses									
Asphalt Concrete	135	155	*	X	X	*	X	*	X	X	X	X
Clay	110	165	*	X	X	A	X	X	X	X	*	*
Concrete	135	150	*	X	X	*	X	*	X	X	X	X
Florogypsum	65+		C	C	X	E	X	X	X	X	C	*
Geotextile	nil		B	*	X	X	B	X	*	X	B	X
Gravel	85	120	*	*	*	*	*	*	*	*	*	*
Limestone	90	150	*	*	*	*	*	*	*	*	*	*
Phosphogypsum	70+		C	C	X	E	X	X	X	X	C	*
Recycled Concrete	90	120	*	*	X	*	*	*	*	*	*	*
Sand	90	110	*	*	*	A	*	*	*	*	*	*
Scoria	light		E	*	*	E	*	E	*	*	E	X
Shell	60	115	*	*	*	*	*	*	*	*	*	*
Spent Bauxite	135+		D	E	X	D	D	D	X	X	*	*
Steel Slag	115+		*	*	*	*	*	E	*	*	*	*

* - Feasible Substitute
A - Feasible When Used in a Sand-Clay-Gravel Mixture
B - Feasible by Possibly Reducing the Amount of Shell Needed
C - Soluble - Stabilization and Dry Environment May be Required
D - More Information Needed - Would Have to be Stabilized
E - More Information Needed - May be a Feasible Alternative
X - Unacceptable
\+ - Number Shown Varies
1 - Lightweight Materials Often Needed Due to Bearing Capacity of Foundation

Florogypsum is a by-product from manufacturing freon. In Louisiana, it is not as plentiful as phosphogypsum. Its radiation compares with soil and other common objects. Gypsum is soluble; therefore, if it is not used below the water table or in water, it may work satisfactorily. Since dry conditions are practically non-existent in southern Louisiana, limited application of this material can be anticipated. There is probably a way to stabilize gypsum so that it becomes insoluble, but this would probably be very expensive. More research and transfer of technology are needed.

Geotextile could mainly be used to reduce the amount of other materials used to construct the items identified in Table 1. It is a proven and accepted construction material in appropriate situations. Installation in calm water is possible, but use in flowing water is restricted due to technical difficulties and cost associated with placement.

Gravel is available from various locations in Louisiana and serves many of Louisiana's construction needs such as concrete aggregate, bituminous aggregate, and as a course aggregate binder in sand/clay base course. Gravel base course does not perform as well as shell in "bridging" over unstable coastal soils. Its use in some applications is limited based on the bearing capacity of the foundation. It is a proven and accepted construction material in appropriate situations.

Limestone is generally considered to be the most acceptable alternate to shell from both a physical and chemical standpoint. It has an angular shape which contributes to the strength of the mass. Presently, limestone must be shipped into Louisiana from the Bahamas, Mexico, Missouri, Illinois, Kentucky, and Alabama. Except in emergencies, the Federal Government will not use any foreign aggregate in Federal

construction projects (Re: Buy American Act) regardless of price and cost differential. It is acknowledged that this restriction does not apply to private works. As with other materials, use of limestone is sometimes limited based on the bearing capacity of the foundation. It is a proven and accepted construction material in appropriate situations.

Phosphogypsum, in raw form, is soluble and has low levels of radiation above minimum safe levels. It is more plentiful in Louisiana than florogypsum. Currently, this material is mixed with cement, spent bauxite, and water, then shaped. This "dilution" reduces the radioactivity level so that it is within an accepted level. More research and transfer of technology is needed.

Sand is abundant in southern Louisiana. Uses for sand are primarily limited to embankments and fill. Sand base course normally requires an admixture of shell, limestone, or gravel to meet stability specifications and usually requires a larger right-of-way than shell. Its use in some applications is also limited based on the bearing capacity of the foundation. It is a proven and accepted construction material in appropriate situations.

Scoria is a potential lightweight substitute in some applications, but not as good as shell because of its generally rounded shape. Scoria's use may be limited due to crushing. More information about its engineering properties are needed. Scoria is available from Mexico and is subject to the Buy American Act.

Shell is used in coastal Louisiana for dike cores and is depended upon heavily because of its light weight, unique shape, high strength, and low cost compared with other alternatives. It is a unique and effective building material in coastal Louisiana. Shell is still specified, with no alternatives, for many construction purposes south of

U.S. Highway 190 in Louisiana. Shell is also specified, with no alternates, for oyster reef cultch, foreshore dikes, and offshore drilling pads.

Spent bauxite and its potential use as a construction material is not well documented. It may be useful when combined with phosphogypsum and Portland cement.

Steel slag is available in small quantities near Laplace, Louisiana. There is a test section with this material being used for levee crown road surfacing. It is not a lightweight material; therefore, its use in some applications is limited based on the bearing capacity of the foundation. More information about its engineering properties are needed.

As discussed above, other materials can be used in place of shells in some cases. As shown in Table 1, except in cases where lightweight materials are needed due to the bearing capacity of the foundation, gravel, limestone, sand, and steel slag can be substitutes for most of the uses of shell. With regard to waste products such as gypsum and spent bauxite, millions of tons of these materials are available, but, to our knowledge, none have been officially approved by any state or Federal agency for use as an alternative to limestone, sand, or gravel. The environmental acceptability of these products is questionable because of radiation, carcinogens, and heavy metals.

The issue of alternative materials is partly one of engineering considerations, but in the final analysis it is best viewed in terms of economics. In the case of clam shells, most applications of the product can be served by a substitute material. However, the matter of interest for each specific application is ultimately the effect on overall project cost or viability when the next best product is substituted. In some cases, the effect of substitution can be expressed simply in terms of the cost differential for the alternate material, while in other cases

redesign of the project may first be required in order to account for the different properties of the materials under study. What must be understood is that any substitution carries with it a cost increase; otherwise the substitute material would have been used in the first place. The concept of marginality tells us that for some projects, a cost increase of any amount, no matter how small, will result in projects being abandoned and the benefits foregone. In other cases, the project cost will merely rise to reflect increased costs of material and/or project redesign, with the added cost being passed on to the end users. This is frequently the taxpayer due to the extensive use of clam shells in road construction and other public works. As cited in Section 3.6.5.1. of the EIS, a savings of $17 million was realized on one Louisiana highway project alone due to both the lower cost of shell and the reduced right-of-way requirement it affords. While it is correct that finite limits to the shell resource exist, as discussed in Section 3.6.1.2, and that eventual substitution and the cost effects thereof will inevitably occur, it is also true that until that time, the cost savings of the shell resource represent a substantial benefit to the public at large.

Clam shells are also used as cultch material for oysters and there has been some interest in whether or not any viable alternatives exist for this use. The Louisiana Department of Wildlife and Fisheries compared oyster setting rates on clam shells and crushed limestone at 10 locations within the Barataria Bay system in southeastern Louisiana from April 15 to October 15, 1981 (Chatry _et al_., 1986). The results of the study are summarized below.

Limestone displayed greater spat catch than clam shells, indicating that limestone is superior to clam shells as a setting substrate, although the reasons for this are unclear. The ability to catch oysters is very important in the selection of cultch material; however, other factors must also be considered. Since limestone is about 1.6 times heavier than clam shells, it would tend to sink faster in soft bottoms.

Limestone is also considerably more expensive. The investigators suggested that a pilot plant should be made using both clam shells and crushed limestone. A comparative assessment of the plants could then be conducted with respect to sinking of the cultch material, spat catch, survival, oyster shape, acceptance to fishermen, and overall cost:benefit ratio.

Based on the available information, no conclusive statements can be made concerning the use of limestone as an alternative to clam shells for use as oyster cultch material.

St. Amant (1959) reported that reef oyster shells (mud shells) and recycled oyster shells (steam shells) provide suitable oyster cultch. However, no comparisons were made between oyster shells and clam shells.

2.2.2. Renew Permits With Existing Conditions

This alternative assumes that shell dredging activities would continue under existing conditions, i.e., as currently permitted and regulated by all agencies involved. A list of regulations imposed upon the shell dredging industry by all agencies is presented in Appendix B. This alternative has been retained for analysis throughout the EIS.

2.2.3. Renew Permits With Additional Restrictions

This is a generic alternative under which a number of possibilities exist. Three major categories have been developed under this alternative and include additional restrictions on areas available for dredging, additional restrictions on dredging intensity, and additional restrictions on the method by which the dredged material is discharged.

2.2.3.1. Additional Restrictions on Areas Available for Dredging

Over the years, numerous areal restrictions have been implemented in the lakes area (Figure 4). With the existing areal restrictions in place, about 44 percent of Lake Pontchartrain is open to the shell dredgers and about 56 percent is restricted. If Lake Maurepas was opened to shell dredging, with the one-mile shoreline restriction in place, about 58 percent of the lake area would be available for dredging. In 1984, DEQ closed Lake Maurepas to shell dredging due to unacceptable water quality impacts. Due to the low salinities, limited tidal exchange, and sediment composition in Lake Maurepas, excessive turbidities have been shown to result from shell dredging in that lake. Unless the shell dredging industry can develop a method to harvest the shells without causing these problems, it is unlikey that shell dredging will be allowed in this lake.

The areal restrictions in the lakes area have been developed through coordination among all interested parties to reduce the environmental impacts of shell dredging and to ensure that the activity does not present a hazard to public safety. In general, these restrictions are logical and the rationale for many of them is obvious. For example, the restricted zones adjacent to the Lake Pontchartrain Causeway, the Southern Railway trestle, and the Interstate Highway 10 twin bridges reduce the risk of the shell dredges and tugs running into these structures and causing structural damage and possible loss of life. The restricted areas adjacent to pipeline corridors are to prevent the dredges from rupturing submerged pipelines. Likewise, the restrictions under the Louisiana Power and Light Company aerial transmission lines are to prevent loss of life and property.

The remaining areal restrictions in the lakes area were developed for different reasons. There is a one (1) mile restricted area around the shoreline of Lake Maurepas. There is also a one (1) mile restricted area around most of Lake Pontchartrain. However, there is a three (3) mile

restricted area on the southern shore of the lake off that portion of Orleans Parish between the Jefferson Parish line and Paris Road.

The shallow, nearshore areas of estuarine waterbodies are more biologically productive than the central portions. These restricted areas also serve as a buffer zone and reduce many of the esthetic impacts. Any noise or unpleasant odors which may result from the dredging activities would be ameliorated by not allowing the dredges to operate too close to shore. Studies have also shown that the highest levels of contaminants in the sediments in Lake Pontchartrain are in the nearshore areas, particularly where canals enter the lake. The restricted area around the shoreline prevents the dredges from stirring up these areas, thereby reducing the potential for release of contaminants into the water column.

The three (3) mile restricted area off Orleans Parish is mandated by the Parish itself to prevent shell dredging activity off a densely populated area. In addition, most of the pollutants entering the lake from Orleans Parish remain within this area and are less likely to be disturbed by shell dredging activities. Also, the relatively high salinities in the vicinity of the Inner Harbor Navigation Canal (IHNC) have been documented to cause reduced levels of dissolved oxygen which tend to stress benthic communities. Restricting shell dredging from this area would lessen the possibility of compounding stress to the benthic communities.

The existing areal restrictions have been developed through cooperation among interested parties. The shell dredging industry has indicated that it can operate in an economically feasible manner under the current areal restrictions. The opponents of shell dredging have not proposed any particular modifications in areal restrictions in the lakes area.

In addition to the areal restrictions in Lake Pontchartrain, the LDWF has created zones and imposed zoning restrictions in the lake (Figure 5). There are ten zones in the lakes area. Nine of the zones are in Lake Pontchartrain. Lake Maurepas is considered a zone by itself. The zoning restrictions were implemented for two primary reasons.

First, the zonation reduces user conflicts between the shell dredgers and other users of the lake, including commercial fishermen and recreationists. Shell dredgers are limited to two zones at a time, with the exception of Zone A, which is in the northernmost portion of the lake just west of the causeway. This zone provides a place for the dredgers to work in inclement weather and is open more often than the other zones. Therefore, at any given time, the shell dredgers are restricted from six areas in Lake Pontchartrain and can only operate in two predetermined zones and Zone A. The schedule under which the shell dredgers operate within these zones is determined annually by the LDWF.

Second, the zonation reduces the dredging pressure in any given area. Since the dredgers have to move from zone to zone on a scheduled basis, the waterbottoms and associated benthos have more chance to recover during periods when they are closed to dredging.

No parties have expressed any particular interest in modifying the zoning scheme; therefore, no alternatives regarding modifications in the zoning process will be considered any further in this EIS.

2.2.3.2. Additional Restrictions on Dredging Intensity

In recent years, there has been controversy concerning dredging intensity in the lakes area. It has been suggested that impacts caused by shell dredging could be decreased by reducing dredging intensity. DNR has regulations which specify that a total of no more than seven dredges shall operate in Lakes Pontchartrain and Maurepas at one time and no more than three shall operate in Lake Maurepas at one time. As discussed in

the previous section, Lake Maurepas is currently closed to shell dredging. The DNR regulations also stipulate that the dredges cannot be altered in any way that would result in an increase in their pumping capacities and total recovery and discharge rates. The shell dredgers are not limited in any way regarding how much time they can dredge, i.e., theoretically they can dredge 365 days a year for 24 hours each day. This, of course, is not possible due to routine maintenance, breakdowns, and inclement weather. The actual figure ranges from 17 to 20 hours per day 270 to 300 days per year. This figure is based on documented pumping times provided by the shell dredging companies that operate in Lake Pontchartrain. Therefore, the existing condition (100 percent dredging intensity) would be seven dredges, as they are currently equipped, dredging at an average rate of 18.5 hours per day for an average of 285 days per year.

A number of alternatives to this base condition exist. However, in order to assess the magnitude of impacts of alternatives in dredging intensity, the *Interdisciplinary Planning Team* (IPT) assembled to prepare this EIS agreed to conduct a preliminary analysis of two alternatives in dredging intensity. Reductions of 25 percent and 50 percent were selected for analysis. These reductions could be achieved by reducing the total number of hours pumped per day, either by: 1) reducing the allowable pumping times of the existing dredges, or; 2) reducing the number of dredges allowed to operate in the lake. Each method represents a different mode of impact on the industry. Method 1 would involve very little impact on fixed costs of production although variable costs would decline as production inputs such as labor, fuel, maintenance, etc., were scaled back. Method 2 would offer the opportunity to achieve at least some reduction in fixed cost from the retirement of capital equipment such as the dredge, tug boats, and barges, in addition to the labor costs and other variable costs saved. The magnitude of fixed cost reduction is highly dependent on the remaining debt obligations for capital equipment, since most of this equipment is highly specialized and consequently has little salvage value.

Representatives of the permit applicants were requested to provide information regarding the economic impacts of these alternatives. Dr. William Barnett II, a local resource economist and technical consultant to the applicants, filed a responding report. This report outlines the likely effects of a reduction in intensity brought about by Method 1. To the extent that a significant debt service remains on any serviceable equipment retired, this report is also illustrative of the expected impacts of Method 2, for the reason cited above.

Dr. Barnett's report indicated that a 25 percent reduction in dredging intensity would force the industry out of business. Obviously a 50 percent reduction would do likewise. The information and analysis leading to this conclusion are presented below. Although the costs and revenues used in the example pertain to the industry as a whole, it was assumed that the percentages shown for fixed and variable costs would be applicable to each firm as well.

Using data provided by the shell dredging industry, fixed costs were estimated to be $8,475,000 annually, or 25 percent of total revenues at the current harvest level of about 3,000,000 cubic yards, while variable costs were estimated at 70 percent of total revenues. Based on the current sales price of $11.30 per cubic yard the gross value of annual production would be $33,900,000. Therefore:

Fixed cost	=	$ 8,475,000
Variable cost	=	23,730,000
Total cost	=	$32,205,000
Total revenue	=	$33,900,000
Total cost	=	-32,205,000
Profit	=	$ 1,695,000

Assuming the same product price, \$11.30 per cubic yard, and a 25 percent reduction in output, total revenues would be \$25,425,000. Therefore:

Fixed cost	=	\$ 8,475,000
Variable cost	=	17,797,000
Total cost	=	\$26,272,000
Total revenue	=	\$25,425,000
Total cost	=	-26,272,000
Loss	=	\$ 847,000

Based on the above calculations, shell dredging would no longer appear to constitute a viable business for any firm if a 25 percent reduction in harvest were to be imposed. It has been suggested, however, that if a reduction in output were imposed on the industry, the resultant scarcity of product would bring about higher prices for the remaining output. This would tend to partly offset revenue losses and thus effectively lower the level of production necessary to break even. In the case cited above, for example, an increase in product price of less than 5 percent would appear to eliminate the \$847,000 loss. As described below, this would not be a likely outcome.

The price/cost structure shown in the example is a highly simplified, static representation of the industry at current levels of production. If it is assumed that, as is likely, current operations are at or below the optimal short run level of output or the optimal long run scale of plant, then forced reduction in production has the effect of driving up the average cost of production as resources are used less efficiently and the economies of scale are lost. In the short run, for example, a 25 percent reduction in permitted output would not likely be accompanied by a perfectly proportionate reduction in variable costs for several reasons: while pumping costs would decline, the fuel required to propel the dredges and tugs would tend to fall to a lesser degree depending on

the method of reduction selected; employees could not be laid off proportionately since minimum manning staffs would have to be retained; vessel maintenance and insurance costs would tend to remain relatively high; increased unemployment compensation would partially negate initial labor savings; etc. To the extent a 1:1 reduction in variable production costs does not occur, a greater increase in product price would be necessary to offset revenue losses. The tolerance of product purchasers (demand elasticity) to such increases is not known and beyond the scope of this analysis, but as an example, if variable cost, as a percent of revenue, rose by 25 percent due to the factors named above, the unit price/increase needed to maintain at least the break-even point would be about $2.35/cu. yd. This results in a price 20 percent higher than the current price. It is speculation to assume that this or any other significant increase could be wholly or partly absorbed by shell users. At the least, marginal construction and maintenance projects requiring substantial amounts of shell would be abandoned due to the increase in material costs, while the costs of all other projects would rise.

For purposes of argument, however, assume that strict proportionality exists between variable cost and output, at least over a production range of ± 25 percent. In such a case, the price increase necessary to recoup revenue losses would be quite small as stated above, and continued operation of all of the dredging companies could be presumed. By definition, however, this degree of output reduction would result in a 25 percent reduction, on the average, in employment of all variable production inputs (labor, fuel, transportation, etc.) with concomitant adverse impacts on primary and secondary labor employment, tax and royalty revenues, unemployment compensation, local purchases of supplies, community cohesion, displacement of people, and the remainder of the entire range of socio-economic variables discussed elsewhere in this document. In view of the current state of the regional economy, few alternative opportunities for employment are likely to be found for these resources, particularly in the short run. Indeed, the notion of a

mandated reduction in economic activity, which after all is what this alternative comprises, would by definition virtually insure that fewer such opportunities exist.

In the case of a reduction in intensity achieved via Method 2, identification of impacts becomes somewhat more difficult. First, the distribution of dredging capacity among the three operators is such that a 25 percent or less reduction in output would have to be borne by only one or two of the companies. Additionally, the remaining debt service on retired equipment, which is variable among the companies, is a necessary component for estimating cost impacts. In any case, however, it would be reasonable to assume that a 25 percent reduction in total industry production imposed on one or two firms within the industry would comprise a major reduction in plant and/or variable input efficiency, which in turn would entail either net operating losses or the need for a substantial increase in product price. This would translate into a loss of competitive advantage compared to the unregulated firm or firms such that continued operation of the affected firm could be expected to be jeopardized.

In summary, a complete description of the price/cost structure of the industry and each operator within it is plainly outside the scope of this study; indeed, much of the required data is proprietary or confidential due to the competitive nature of the enterprise. Such a description, however, is not necessary in order to understand in general terms the most likely impacts that could be expected to result from mandated reductions in output on any business, particularly one such as the shell industry, which has been stressed by similar measures in the recent past. While detailed analysis of fixed and variable costs at present levels of production, and estimates of same at reduced levels of output theoretically would reveal the exact adjustments in input mix and plant scale which could minimize the adverse impacts of reduced operations forced on the industry (assuming operations could continue at all), the cost in time and money of developing such an analysis would be both

extreme and unwarranted. It would only permit quantification of economic impacts which already can be adequately described qualitatively.

Although the impacts of shell dredging have been quantified where possible in this EIS, much of the environmental impact analysis is of necessity qualitative in nature. Based on this information, it is not likely that the positive environmental impacts resulting from a 25 percent reduction in dredging intensity would be measurable. However, from a socio-economic viewpoint, it appears that such a reduction would entail at the least substantial adverse impacts and could conceivably force one or more of the shell dredging companies out of production and essentially out of business. Therefore, this alternative was eliminated from further consideration.

2.2.3.3. Additional Restrictions on Dredge Discharge

There is considerable interest regarding the effects of dredge discharge and the manner in which material is discharged from the dredges. This interest is primarily due to concern over turbidity and other water quality impacts. Due to this interest, DNR required as part of their January 26, 1983 permits that the three dredging companies operating in the lakes area prepare comprehensive engineering studies to investigate this matter. Three reports were prepared and are cited in Section 1.3 of this EIS. The studies were to address the feasibility of decreasing the pressure of the discharge, extending the discharge pipes for subsurface discharge, and using some type of modified silt screening system to reduce turbidity.

The primary reason for considering a decrease in the velocity of the discharge is apparently due to concern for bottom disturbance created by the discharge (Steimle and Associates, 1985). It should be emphasized that the discharges are not "pressure" discharges, but are gravity flow. The discharges do, however, create disturbance in the water column as the material is discharged behind the dredge. In addition to disturbance

caused by the discharges, considerable disturbance is also created by propeller wash. The engineering studies investigated several ways to reduce the velocity of the discharge before entering the water. These included placing a box beneath the discharge to dissipate the velocity of the flow before entering the water, placing baffles or obstructions in the discharge pipes, turning the pipes upward prior to entry into the water, and several other measures. Although these options would reduce the discharge pressure, a number of engineering problems arose. Obstructions in the pipes or turning the pipes upward causes clogging problems. Using a box beneath the discharge pipes may be viable, but it may only enhance the effects of problems caused by the propeller wash (Steimle & Associates, 1985).

Submerging the discharge pipes a short distance beneath the surface appears to have some merit in that it reduces water surface effects. Some of the dredges have submerged discharge pipes at present. Submerging the pipes too deep would cause more disturbance of the bottom.

The studies demonstrated that silt screens are clearly infeasible as a mechanism for reducing turbidity caused by shell dredging activities. Silt screens can be very effective in stationary dredging operations, particularly in areas with minor current actions. However, the fact that the dredges move continuously, combined with the currents and wave action in the lake, preclude the effective use of silt screens to reduce turbidity.

It would be extremely difficult to frequently relocate a silt screen to keep pace with the movement of the dredge. Considerable time and manpower would be needed to effectively control and move the screen, which would need to contain a very large area downcurrent of the dredge at all times. The length of time required to move the screens would require that the area isolated be on the order of square miles, large enough that normal settling time (usually hours) would protect adjacent areas equally as well as the screens.

It should be noted that in certain seasons such as spring, summer, and winter, strong thunderstorms and frontal passages range from daily to weekly occurrences, and would greatly hinder movement and efficiency of silt screens.

In summary, the engineering studies demonstrate that certain modifications can be made to the dredge discharges to reduce turbidity impacts. The reports actually provide specific recommendations for modifying the discharges for particular dredges. Since each dredge has a different discharge configuration and different discharge velocities, suggested modifications must be approached on a dredge by dredge basis.

2.4. **Renew Permits With Reduced Restrictions**

In the previous section, discussions concerned additional restrictions under three general categories, including areas available for dredging, dredging intensity, and modifications to dredge discharge. This section will address the feasibility of reduced restrictions under these same categories.

2.2.4.1. Reduced Restrictions on Areas Available For Dredging

The areal and zoning restrictions in the lakes area are the result of coordination and negotiation among various interested parties. During the scoping process, the generic alternative of reduced restrictions was identified. However, no specific recommendations concerning what reduced restrictions warrant consideration were brought forth. As discussed in the previous section, no additional restrictions were recommended for detailed examination in the EIS. Likewise, there appears to be no sound reason to consider reducing any of these restrictions, particularly in light of the extensive concern and controversy concerning the environmental impacts of shell dredging in the lakes area.

Representatives of the shell dredging industry recognize the concerns regarding impacts of shell dredging and have not requested any reductions in dredging restrictions in the lakes area.

2.2.4.2. Reduced Restrictions on Dredging Intensity

The current DNR restrictions on dredging intensity in the lakes area limit the three companies that work in the area to a total of seven dredges. Based on the current DNR permit, the pumping and discharge capacities of these seven dredges cannot be increased. The seven dredges constitute the total number of dredges currently available to these companies. Since it is unlikely that more dredges will be constructed, and in light of the public concern to reduce dredging intensity, no alternatives to reduce restrictions on dredging intensity are considered further.

2.2.4.3. Reduced Restrictions on Dredging Discharge

Concern over water quality and associated biological impacts have prompted suggestions that methods be devised to reduce the impacts of the dredge discharge. However, during scoping, no specific suggestions regarding lessening of discharge restrictions were offered. In addition, DNR's permits state that the discharge capacities of the seven dredges operating in the lakes area cannot be increased. Therefore, consideration of alternatives to reduce restrictions on dredge discharge do not warrant further consideration in the EIS.

2.3. ALTERNATIVES CONSIDERED IN DETAIL

Based on the preceding analysis, two alternatives are retained for detailed consideration.

ALTERNATIVE 1 - Renew Permits With Existing Conditions (Applicant's Proposal)

ALTERNATIVE 2 - No Federal Action (Permit Denial)

According to ER 200-2-2, Appendix B, "Environmental Operating Procedures and Documents for Regulatory Functions," the EIS will provide an in-depth evaluation of those reasonable alternatives which are both practical and:

"(i) Within the capability of the applicant and within the jurisdiction of the Corps of Engineers. (These alternatives may encompass the Corps alternative to issue the permit as requested or to issue with mitigating conditions. It may also encompass the alternative to deny the permit with a view toward accomplishing the objective of the proposal by the applicant (or by any other party) by some other means or at some other site still within Corps jurisdiction.)

(ii) Within the capability of the applicant but outside the jurisdiction of the Corps of Engineers. (This alternative may include denial of the permit with a view toward accomplishing the objective of the proposal by the applicant (or any other party) outside of Corps jurisdiction.)

(iii) Reasonably foreseeable, beyond the capability of the applicant but within the jurisdiction of the Corps of Engineers. (This alternative may include the do-nothing or deny alternative, with a view toward the satisfaction of the public and/or private need by some other entity beyond the control of the applicant but within the jurisdiction of the Corps of Engineers.)

(iv) Reasonably foreseeable, although beyond both the capability of the applicant and outside the jurisdiction of the Corps of Engineers. (This alternative may include the do-nothing or deny alternative, with a view toward the satisfaction of the public and/or private need by some other entity beyond the control of the applicant and beyond the scope of the Corps of Engineers.)

The EIS should clearly identify alternatives discussed in detail by the above categories."

Alternative 1 is within the capability of the applicant and within the jurisdiction of the Corps of Engineers. Alternative 2 is reasonably foreseeable, although beyond both the capability of the applicant and outside the jurisdiction of the Corps of Engineers. Permit denial is within the jurisdiction of the Corps; however, in this case, permit denial means that an alternative material would be used as a substitute for shells and may not fall under the jurisdiction of the Corps.

Section 3 (EXISTING CONDITIONS AND IMPACTS OF ALTERNATIVES) discusses the impacts of these two alternatives on the significant resources/issues addressed in this EIS.

2.4. COMPARATIVE IMPACTS OF ALTERNATIVES

The following table summarizes the impacts of the two alternatives investigated in detail on each significant resource/issue.

COMPARATIVE IMPACTS OF ALTERNATIVES

Significant Resource/Issue	Alternative 1 Renew Permits With Existing Conditions	Alternative 2 No Federal Action (Permit Denial)
Geological Resources		
Mineral Resources	Existing areal restrictions protect oil and gas structures and pipeline corridors.	No impact on future oil and gas exploration.
Water Quality/Sediments		
Water Quality	Dredging causes short-term turbidity and increased levels of suspended sediments in the vicinity of the dredge and may contribute to the long-term increase in lakewide turbidity, although the extent is unknown. Contaminant and nutrient levels in the water column are elevated during dredging but return to ambient levels in a short period of time.	Short-term turbidity due to dredging would be eliminated and there would be no contribution to long-term turbidity increase. Temporary increase in levels of nutrients and contaminants in the water column due to shell dredging would no longer occur.
Sediment Quality/ Contaminants	Since highest levels of contaminants occur in nearshore sediments in area where dredging is prohibited, problems related to release of contaminants appear to be minimal.	No potential for shell dredging-related release of contaminants from lake sediments.
Sediments/Physical Characteristics	Bottom sediments are less consolidated for a period of time after dredging and more prone to resuspension by wave activity. Dredging produces a thin layer of fluid mud along the dredge path that spreads in response to bottom current until its density is sufficient to resist further movement.	Bulk density of sediments would tend to gradually revert to their former pre-dredging state. The fluid mud layer produced by shell dredging would no longer exist and the bottom sediments would be less prone to resuspension by wave activity.
Biological Resources		
Grassbeds	Since the grassbeds are all located in nearshore areas where dredging is prohibited, there are no direct impacts to these beds due to dredging or short-term turbidity. It is believed that the long-term increase in turbidity in Lake Pontchartrain has adversely impacted grassbeds, but the contribution of shell dredging to this increase is unknown.	Impacts to grassbeds due to any shell-dredging induced increases in long-term turbidity would be eliminated.

COMPARATIVE IMPACTS OF ALTERNATIVES (Cont'd)

Significant Resource/Issue	Alternative 1 Renew Permits With Existing Conditions	Alternative 2 No Federal Action (Permit Denial)
Phytoplankton	Short-term turbidity during dredging activities temporarily decreases phytoplankton production in the vicinity of the dredge. Since less than one percent of the area of the lake is affected at any given time even with all dredges operating, this short-term loss is not considered significant. Impacts of the long-term increase in turbidity on phytoplankton, in which shell dredging has likely played a role, are unknown.	Temporary, localized impacts to phytoplankton and primary productivity in the vicinity of the dredge would be eliminated and there would be no contribution to long-term turbidity increase.
Benthos	Shell dredging has been a major factor in the decease in abundance of large clams (Rangia) in Lake Pontchartrain and has been a factor in the establishment of a benthic community dominated by highly opportunistic species.	To the extent that all of the other perturbations affecting the lakes would allow, the benthic community would gradually "recover" to its predredging state, although it would take a number of years for widespread populations of large Rangia to become established.
Fisheries	Although there has been a decline in abundance and frequency of occurrence of certain demersal fish species in Lake Pontchartrain, there are no data to indicate the shell dredging has adversely impacted these resources. These fishes do not generally consume large clams and are very opportunistic feeders, consuming whatever benthic organisms are available.	Any impacts to fishery resources due to the periodic disturbance of bottom sediments and benthos by shell dredging would be eliminated.
Wildlife	Shell dredging exerts minimal impacts on wildlife resources, which primarily utilize the nearshore areas of the lakes. Lesser scaup feed in the open-lake areas, but consume small Rangia and other benthic organisms, which are still plentiful.	Since shell dredging exerts minimal impacts on wildlife, impacts would be the same as Alternative 1.
Endangered and Threatened Species	The only species that could be affected are the Atlantic ridley and loggerhead sea turtles and it has been concluded that impacts to these turtles is negligible.	Any possible impacts to endangered and threatened species, however slight, would be eliminated.

COMPARATIVE IMPACTS OF ALTERNATIVES (Cont'd)

Significant Resource/Issue	Alternative 1 Renew Permits With Existing Conditions	Alternative 2 No Federal Action (Permit Denial)
Economic Resources		
Business and Industry	Shell dredging industry would continue to harvest shells for the next 17 to 25 years. Economic forces would likely force one or more companies out of business as shells are depleted.	Industry would shut down causing loss of employment, income, and capital investments. There would be an estimated loss of about $29 million in capital investments. Cost of alternative materials would increase due to market forces, increasing cost pressure on local industries.
Desirable Regional Growth	Renewal of permits would have only an incremental impact on overall regional growth as shell dredging represents only a small portion of the area's economic activity.	Economic development would continue, but the restructuring of basic materials industries could have a negative impact on regional growth.
Employment/Labor Force	The 302 jobs directly related to dredging and an estimated 906 jobs indirectly involved would be sustained until the resource begins to be depleted. About $27 million in direct and indirect annual income would be sustained.	Estimated loss of 725 jobs due to direct and indirect impacts and a loss of about $16.5 million in earnings in the first year. Higher cost of alternative materials would increase overall cost of production and construction.
Property Values	The $30 million estimated value of the specialized equipment used by the industry would be sustained as long as economically recoverable shell exists.	Estimated loss after salvage of about $29 million in dredging equipment. Loss of employment could adversely affect the local housing market, which is already depressed.
Public Facilities and Services/ Transportation	Royalties and severance taxes paid to the state by the dredgers would continue to be available until the resource is depleted. Shell would continue to be available to build roads and other public facilities.	Immediate impact on highway and other construction activities. Other aggregates would have to be imported Amount of revenue from royalties and taxes would no longer be available for use by the state.
Tax Revenues	Taxes generated by the industry would continue to be available. Tax revenues used to monitor and enforce industry operations would continue to be expended.	Severance, sales, and income taxes generated by shell dredging would no longer be available, but some taxes would be generated by use of alternative materials.

COMPARATIVE IMPACTS OF ALTERNATIVES (Cont'd)

Significant Resource/Issue	Alternative 1 Renew Permits With Existing Conditions	Alternative 2 No Federal Action (Permit Denial)
Social Environment		
Esthetic Values	Since dredging activities are restricted near the shoreline, esthetic impacts in Lake Pontchartrain are limited to the vicinity of the dredge and are not considered significant. Impacts to esthetic values in Lake Maurepas could be significant due to lakewide elevated levels of turbidity caused by shell dredging.	Any impacts to esthetic values as a result of shell dredging would be eliminated.
Archeology/Cultural Resources	Impacts to underwater cultural resources are addressed under existing permit regulations.	Permit denial would eliminate any possibility of impacts to cultural resources.
Desirable Community Growth	Employment and income generated by the industry would stimulate community development. Continued availability of shell at competitive prices would help sustain growth in local areas.	Loss of employment would likely force some local residents to seek jobs elsewhere. Higher cost of alternative materials could discourage growth in the area.
Community Cohesion	Considerable disagreement exists regarding the environmental impacts of shell dredging. Conflict within the community would continue under this alternative.	Social harmony of the area would be adversely impacted due to estimated loss of 725 jobs and associated equity issues. Conflict between user groups would lessen to some extent.
Noise	High noise levels would be limited to areas in the immediate vicinity of the dredge.	Dredge noise would be eliminated.
Recreation	Restricted areas along the shore minimize any impacts to recreationists along the shoreline of Lake Pontchartrain. Impacts can occur in the immediate vicinity of dredges in Lake Pontchartrain if fishermen desire to fish in the particular area where dredges are working. Adverse impacts to recreational fishing in Lake Maurepas could be significant due to lakewide elevated levels of turbidity.	Conflicts between dredgers and recreationists would be totally eliminated.

COMPARATIVE IMPACTS OF ALTERNATIVES (Cont'd)

Significant Resource/Issue	Alternative 1 Renew Permits With Existing Conditions	Alternative 2 No Federal Action (Permit Denial)
Displacement of People	Local employment and income would be sustained. Population displacements would be limited, although employment would gradually decline as the resource is depleted.	Loss of estimated 725 jobs would contribute to unemployment and outmigration that is already a critical problem in this depressed area.
Public Safety	The risk of the Causeway being struck by shell dredging vessels or equipment would still exist, but at an extremely low level of probability with careful operation of CAWS.	Permit denial would eliminate the risk of shell dredging equipment striking the Causeway although the possibility of other commercial vessels hitting the bridge would still exist.

3. EXISTING CONDITIONS AND IMPACTS OF ALTERNATIVES

3.1. INTRODUCTION

This section provides a general description of the study area, including the location and geological history of the area. Following this introduction, each significant resource/issue identified through the scoping process is discussed under existing conditions and future conditions without shell dredging.

3.2. LOCATION AND ENVIRONMENTAL SETTING OF PROPOSED ACTIVITY

The general location of the proposed activity is shown in Figure 1. The areas where shell dredging activities have historically occurred include Lakes Maurepas and Pontchartrain. These lakes are shallow, relatively flat-bottomed waterbodies with salinities ranging from fresh to brackish.

Lake Maurepas occupies an area of about 93 square miles and has a maximum depth of about 12 feet. The average depth of the lake is about 7 feet. The principal streams flowing into the lake are the Amite, Blind, and Tickfaw Rivers. Lake Maurepas is connected to Lake Pontchartrain by North Pass and Pass Manchac. Salinities in the lake are generally near zero in the western portions and average about 1.5 ppt in Pass Manchac. Tides are chiefly diurnal and fluctuations are minimal, with the normal tide range being about 0.3 feet. Lake Maurepas is surrounded primarily by fresh marsh and wooded swamp. The drainage area of the lake at the mouth of Pass Manchac is about 3,245 square miles.

Lake Pontchartrain is considerably larger than Maurepas, occupying an area of about 630 square miles. The maximum natural depth of the lake is about 16 feet, with more than 75 percent of the lake being 10 feet deep or greater. The major tributaries entering the lake are the Tangipahoa

and Tchefuncte Rivers and Bayous Lacombe and Bonfouca. The Bonnet Carre' Spillway is an intermittent source of flow and sediments when used for flood control on the Mississippi River. The drainage systems of Jefferson and Orleans Parishes discharge storm flows into Lake Pontchartrain on the south shore. The Rigolets and Chef Menteur Pass are natural tidal passes between Lakes Pontchartrain and Borgne. The Inner Harbor Navigation Canal (IHNC), Gulf Intracoastal Waterway (GIWW), and Mississippi River-Gulf Outlet (MR-GO) are manmade, navigable waterways that interlink the Mississippi River, Gulf of Mexico, and Lake Pontchartrain.

Salinities in the lake normally range from about 3-8 ppt at the Rigolets to about 0-2.5 ppt at Pass Manchac. Higher salinities often occur in the vicinity of the IHNC, particularly in the summer and fall. The normal tidal range in the lake is about 0.5 feet. The range of the tides in Lake Pontchartrain is frequently modified by wind. Water levels are generally lowest in early winter, rise through early summer, rise to a peak in late summer, and decline through the fall. Lake Pontchartrain is surrounded by fresh, intermediate, and brackish marshes, wooded swamp, and urban areas. The drainage area of Lake Pontchartrain at the Rigolets is about 5,558 square miles, including the surface area of the lake.

Lake Pontchartrain receives about one-half of its fresh water input from headwater flows and about one-half from the tidal passes. The Pearl River is the main source of fresh water entering the lake through the passes and the Amite River is the main source of headwater flow via Lake Maurepas. Salt budget calculations indicate that the Rigolets supplies 40 percent, Chef Menteur Pass 40 percent, and the IHNC 20 percent of the total salt entering the lake.

Water circulation in Lake Pontchartrain is dominated by an easterly wind with either a northern or southern component depending on the season. Wind speeds greater than 15 mph, which occur about 15 percent of the time, cause bottom sediments to become resuspended in the water

column. The general water circulation pattern for both flood and ebb tides is a littoral drift to the west along the southern and northern shores, with a return current in a broad band of water running approximately from the northwest to the southeast. Center currents and eddies exist in the lake and sometimes modify this predominant pattern. Operation of the Bonnet Carre' Spillway changes the circulation pattern to an easterly flow near the southern shore and at mid-lake.

In addition to affecting tides and circulation patterns, wind also affects the exchange of water between Lakes Maurepas and Pontchartrain. A southeasterly wind sets up Lake Pontchartrain, reducing the net outflow from Lake Maurepas. The presence of a southeasterly wind in the spring can force water into Lake Maurepas and up into the surrounding marshes.

3.3. GEOMORPHIC HISTORY OF AREA

The Pontchartrain Basin is roughly oval with its major axis extending about 75 miles in an east-west direction from a point about 8 miles east of Donaldsonville to the mouth of the Pearl River. The surface and nearsurface sediments in the basin consist of alluvial deposits by the Mississippi River and, to a minor extent, alluvial deposits from smaller streams that enter the basin from the north. Formation of the basin occurred as the Pleistocene deposits subsided, sea level rose, and the Gulf of Mexico encroached creating a shallow marine embayment. Continued advance of the Mississippi River into the general area resulted in an influx of alluvial sediments which continued until the formation of the St. Bernard Delta to the south and southeast; at which time the basin was isolated from the Gulf and the Mississippi River by a system of natural levees. Alluvial sedimentation continued via the Mississippi overbank flow and other minor streams, but subsidence became the dominant process and the lakes in the area expanded rapidly to their general present configuration.

Lake Pontchartrain is the focal point of the basin. It is classified as a brackish-water lake as a result of the mixing of fresh water from upland areas to the north and saline waters which enter the lake from the Gulf through the Rigolets, Chef Menteur Pass, and the IHNC via the MR-GO. Formation of the lake was initiated as a result of continued outbuilding of the various Mississippi River deltas and culminated when the river was occupying the St. Bernard course. During this period of development of the St. Bernard delta, formation of natural levee ridges along the southern edge of the lake effectively isolated the lake from the gulf.

3.4. PHYSICAL ENVIRONMENT

3.4.1. **Geological Resources**

3.4.1.1. Mineral Resources

3.4.1.1.1. Existing Conditions

Current mineral resources found in the lakes area, in addition to shells, consist of oil and gas. Production of oil and gas in Lake Maurepas occurs primarily in the extreme western part of the lake in Livingston Parish. Production of oil and gas in Lake Pontchartrain is limited to the southern part of the lake approximately 1.5 to 5.0 miles from the shoreline in St. Charles and Jefferson Parishes.

3.4.1.1.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Restrictions

This alternative would have no impact on existing mineral production because the existing areal restrictions provide protective zones along pipeline corridors and in the vicinity of oil and gas structures. These restrictions are presented in Appendix B.

Alternative 2 - No Federal Action (Permit Denial)

The No Action alternative would have no impact on existing oil and gas exploration.

3.4.2. **Water Quality/Sediments**

3.4.2.1. Water Quality

3.4.2.1.1. Existing Conditions

Salinity

Data from several salinity monitoring stations are presented in Tables C-1 through C-4 of Appendix C. The data indicate that the lowest salinities are generally in the late spring and highest in the summer and fall. This reflects seasonal variations in freshwater inflows from the major rivers and streams. The salinities of Lakes Pontchartrain and Maurepas normally range from fresh to brackish. Salinities average less than 0.2 ppt in Lake Maurepas while averaging about 4.1 ppt in Lake Pontchartrain. The lowest mean monthly salinity in Lake Pontchartrain (2.6 ppt) occurs in May while the maximum (5.9 ppt) occurs in October. The salinity regime is subject to drastic change during floods on the rivers and streams discharging into Lake Maurepas and Pontchartrain, Bonnet Carre' Spillway openings, and hurricanes.

General Water Quality

Data for the general water quality characterization of Lake Maurepas and Pass Manchac are presented in Table C-6 of Appendix C.

Water temperatures of both locations averaged between 21 and 22°C over the respective periods of record. The mean of the dissolved oxygen record for the Lake Maurepas sampling location is 8.2 mg/L and the average of the dissolved oxygen record for the Pass Manchac sampling station is 8.1 mg/L. The record of 5-day biochemical oxygen demand

(BOD5) measurements for the Lake Maurepas sampling station averages 1.4 mg/L; individual observations range from 0.0 to 8.3 mg/L. BOD5 was not measured for the Pass Manchac sampling station. The chemical oxygen demand (COD) data for the Lake Maurepas sampling station range from 5 mg/L to 95 mg/L and average about 30 mg/L. COD data for the Pass Manchac sampling station average about 54 mg/L and range from zero to 175 mg/L. The PH data for both stations indicate that pH was within applicable state standards. Total alkalinity measurements (a measure of buffer capacity) average about 23 mg/L for the Lake Maurepas data and about 35 mg/L for the Pass Manchac data. It appears that the waters of Lake Maurepas are not too well buffered. The sample means of total dissolved solids, total chloride, and total sulfate are reflective of the influence of inflows from Lake Pontchartrain on values measured at the Lake Maurepas and Pass Manchac sampling locations. Total dissolved solids data for the Pass Manchac sampling station range from 30 mg/L to 6,846 mg/L and average about 1,442 mg/L. The means of the total chloride and total sulfate data for the Pass Manchac sampling station are 809 mg/L and 95 mg/L, respectively. By comparison, chloride and sulfate data average 160 mg/L and 28 mg/L, respectively, for the Lake Maurepas sampling location. Both the mean concentrations for the nitrite plus nitrate and total phosphorus data are significantly higher for the Lake Maurepas sampling location compared to the Pass Manchac location. The average of the nitrite plus nitrate data for Lake Maurepas is about 219 ug/L-N, about 56 percent greater than the 140 ug/L-N mean for Pass Manchac. The mean of the total phosphorus data for Lake Maurepas is about 142 ug/L-P, about 41 percent greater than the 101 ug/L-P mean of the Pass Manchac data. Generally, these data suggest that Lake Maurepas functions as a nutrient sink, removing much of the nutrient load of its upstream tributaries from the water column.

Water quality data used to assess the general character of Lake Pontchartrain are presented in Table C-7 of Appendix C. The computed mean values of the listed parameters are fairly consistent for all of the sampling locations.

In general, the means of water temperature observations are about 20°C and those for dissolved oxygen, about 8 mg/L. Mean values of BOD5 are similar at all stations, ranging from 1.4 to 1.7 mg/L. The measurements of total organic carbon range from 0 to 55 mg/L, with sample means ranging from 5.6 to 9.1 mg/L.

Chemical oxygen demand measurements range from 5 mg/L to 560 mg/L, with sample means of COD ranging from 31 mg/L to 156 mg/L. Examination of the data for pH reveals relatively infrequent instances of measured values below the 6.5 minimum state standard, while there were no instances of pH exceeding the maximum standard of 9.0. The distribution of total alkalinity sample means ranges from about 24 to 55 mg/L-CaC03. Overall, total alkalinity ranged from 0 mg/L-CaC03 to 326 mg/L-CaC03 and averaged about 36 mg/L-CaC03. Measurements of total nonfilterable residue (suspended solids) at the various locations in Lake Pontchartrain range from zero to 336 mg/L and average about 23 mg/L. The station means are fairly consistent, ranging from 18 mg/L to 29 mg/L. Turbidity closely follows the same pattern as suspended solids. Station means range from 11 JTU's to 22 JTU's. Collectively, turbidity measurements average about 17 JTU's and range from zero to 150 JTU's. Observations of total nitrite plus nitrate concentrations in Lake Pontchartrain range from zero to 2.5 mg/L-N. The station means are similar, with mean concentrations ranging from 0.08 mg/L-N to 0.56 mg/L-N. Observations of total phosphorus concentrations in the lake average about 0.1 mg/L-P overall. The station means are consistent, with values all close to the 0.1 mg/L-P total mean.

3.4.2.1.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

The Louisiana Department of Environmental Quality (DEQ) conducted a "Hydraulic Clam Shell Dredging Investigation" in 1983 and 1984. In that

investigation, they collected water samples before, during, and after passage of operating dredges.

The May 1983 DNR investigation was designed to gain insight into the magnitude and duration of any chemical changes that might occur in the water column as sediments are released from the shell dredges operating in Lake Pontchartrain. Three sampling boats were utilized for collecting water samples before and after passage of an operating dredge at the following time intervals.

1 hour before (minus 1 hour)
Immediately following dredge passage (0 hours)
1 hour after dredge passage (plus 1 hour)
4 hours after dredge passage (plus 4 hours)
8 hours after dredge passage (plus 8 hours)
24 hours after dredge passage (plus 24 hours)
A dredge effluent sample was also collected

Boat I was positioned at an arbitrary point 1 hour travel time in front of the dredge. Boats II and III were aligned at 1/4 mile intervals along the direction of flow from Boat I. Table 2 shows the constituents and their values experienced during this investigation at the surface and bottom and in the dredge effluent. Table 3 shows dissolved oxygen levels measured at multiple depths throughout the investigation. These data show ambient level concentrations for nitrite/nitrate and total organic carbon in dredged effluents. Elevated levels of Kjeldahl nitrogen, ammonia, total phosphorus, BOD5, COD, turbidity, alkalinity, TSS, TDS, and total solids were present in the dredge effluent. The level of all constituents in the 1 meter depth sample were at ambient levels 1 hour after passage of the dredge. At the 4.5 meter depth, turbidity, TSS, and total solids were measured at ambient levels 4 hours after passage of the dredge. Dissolved oxygen readings measured during this investigation indicate that levels remained consistently high at all depths during and after passage of the dredge. All concentrations were well above the 4.0 mg/l state criterion for that parameter.

TABLE 2

Constituents and Values Measured During the May 24, 1983 DEQ Investigation

(Boat I)

Time (Hours)	Nitrite/ Nitrate (mg/L)	Kjeldahl Nitrogen (mg/L)	Ammonia (mg/L)	Total Phosphor. (mg/L)	BOD.5 (mg/L)	COD (mg/L)	Turbidity NTU's	Alkalin. (mg/L)	TSS (mg/L)	TDS (mg/L)	Solids (mg/L)	TOC (mg/L)
1 Meter Depth												
-1	0.12	0.67	0.11	0.05	0.8	47.3	19	29	11	1219	1230	5.5
0	0.13	0.72	0	0.09	0.9	55.7	56	29.8	88	1278	1366	4.6
1	0.11	0.67	0	0.05	0.95	61.9	21	29.6	19	1227	1246	5.5
4	0.1	0.58	0	0.05	1.2	66	24	29.6	17	1225	1242	5.5
8	0.07	0.61	0	0.04	1.8	59.8	18	28.8	10	1204	1214	5.6
24	0.09	0.7	0	0.05	0.6	47.3	17	29.6	12	1246	1258	5.6
4.5 Meter Depth												
-1	0.12	1.22	0.005	0.11	1.3	53.9	20	29.6	14	1312	1326	6.5
0	0.14	1.64	0.016	0.48	1.1	113.8	320	37.6	740	1320	2060	5
1	0.14	0.77	0	0.09	0.21	68.1	70	30.4	72	1348	1420	5.2
4	0.12	0.53	0	0.04	0.7	57.7	21	29.2	16	1278	1294	5.6
8	0.09	0.58	0	0.05	1.2	57.7	22	29.6	15	1353	1368	5.6
24	0.09	0.69	0	0.04	0.43	49.4	20	29.4	12	1262	1274	5.6
Dredge Effluent												
	0.14	29.7	0.8	6.72	17.61	942.5	6000	900	22343	1830	24173	6.5

Time Legend

-1 1 hour before dredge passage
0 Immediately following dredge passage
1 1 hour after dredge passage
4 4 hours after dredge passage
8 8 hours after dredge passage
24 24 hours after dredge passage

TABLE 3

Dissolved Oxygen Levels (mg/L) Measured at Multiple Depths During the May 24, 1983 DEQ Investigation

BOAT	TIME (Hours)	DEPTH 1 METER	2 METER	3 METER	4 METER	4.5 METER
LPI	-1	7.9	8.0	8.1	8.9	8.9
	0	7.3	7.1	7.0	7.0	6.9
	1	7.4	7.2	6.9	6.7	6.3
	4	7.7	7.7	7.6	7.2	7.0
	8	8.6	7.7	7.2	6.9	6.3
	24	7.8	7.8	7.7	7.7	7.7
LPII	-1	7.8	7.6	7.3	7.5	7.0
	0	8.5	7.4	7.5	6.9	6.9
	1	8.0	7.7	7.0	8.2	8.0
	4	8.4	7.7	7.6	7.5	7.2
	8	8.6	7.8	7.6	7.6	7.5
	24	7.5	7.4	7.4	7.3	7.3
LPIII	-1	7.9	7.9	7.9	7.8	7.5
	0	7.8	7.7	7.7	7.6	7.3
	1	7.9	7.7	7.6	7.6	7.1
	4	8.0	7.3	7.3	7.3	6.8
	8	9.2	8.2	7.8	7.8	7.6
	24	7.4	7.3	7.3	7.2	7.1

TIME LEGEND

-1	1 hour before dredge passage
0	Immediately following dredge passage
1	1 hour after dredge passage
4	4 hours after dredge passage
8	8 hours after dredge passage
24	24 hours after dredge passage

Dissolved oxygen readings taken during the DEQ November 1983 investigation are shown in Table 4. The levels of dissolved oxygen remained consistently high during the investigation and no values below the state criterion of 4.0 mg/L were observed. A control point was used during this investigation; a boat was stationed outside the influence of the dredges to record natural fluctuations in dissolved oxygen.

Dissolved oxygen readings taken during the DEQ September 1984 investigation are shown in Table 5. The level of dissolved oxygen remained consistently high at the 1, 2, and 3 meter depth locations and did not violate the state's criterion. Interestingly, at the 4.5 meter depth location, dissolved oxygen was below the criterion before passage of the dredge, but improved at this depth during and following passage of the dredge.

Perhaps the most noticeable impact to water quality as a result of shell dredging is the short-term turbidity in the vicinity of the dredge. Shell dredging may also contribute to the overall long-term turbidity increase in Lake Pontchartrain, although the extent of the contribution is unknown.

<u>Alternative 2</u> - No Federal Action (Permit Denial)

Total cessation of shell dredging activities would, of course, eliminate any possibility for release of contaminants into the water column due to dredging. The short-term, localized increase in turbidity and suspended sediments in the vicinity of dredging activities would no longer occur. To the extent that shell dredging has contributed to the apparent overall long-term increase in lakewide turbidity, these potential impacts would be eliminated as well. However, other factors may continue to contribute to long-term increases in turbidity.

TABLE 4

Dissolved Oxygen Levels (mg/L) Measured During
the November 1, 1983 DEQ Investigation

BOAT	TIME (Hours)	DEPTH 1 METER	2 METER	3 METER	3.3 METER	4 METER	4.5 METER
LPI	-1	7.4	7.4	7.4	7.0		
	0	7.1	6.9	6.6	6.5		
	0.5	7.0	7.1	7.0	6.7		
	1	7.0	6.9	6.8	6.8		
	1.5	7.0	7.0	6.8	6.8		
LPC (Control Boat)	-1	8.6	8.5	8.6		8.6	8.5
	0	8.7	8.4	8.3		8.4	8.2
	0.5	8.7	8.5	8.5		8.3	8.2
	1	8.6	8.5	8.5		8.4	8.4
	1.5	8.3	8.3	8.3		8.3	8.3

TIME LEGEND

-1	1 hour before dredge passage
0	Immediately following dredge passage
0.5	0.5 hours after dredge passage
1	1 hour after dredge passage
1.5	1.5 hours after dredge passage

TABLE 5

Dissolved Oxygen Levels (mg/L) Measured
During the September 13, 1984 DEQ Investigation

BOAT LPI	TIME (Hours)	DEPTH 1 METER	2 METER	3 METER	4 METER
	-1	8.1	7.9	7.3	2.5
	0	7.9	7.3	7.5	5.9
	0.5	8.2	8.1	6.9	6.0
	1	8.3	8.0	6.1	5.1
	1.5	7.8	6.6	4.1	3.9
	3	8.8	8.2	6.0	4.3
	6	8.0	5.3	4.2	3.0

TIME LEGEND

-1	1 hour before dredge passage
0	Immediately following dredge passage
0.5	0.5 hours after dredge passage
1	1 hour after dredge passage
1.5	1.5 hours after dredge passage
3	3 hours after dredge passage
6	6 hours after dredge passage

3.4.2.2. Sediment Quality - Contaminants

3.4.2.2.1. Existing Conditions

The most recent extensive sediment composition data available were obtained by DEQ as part of a "Water Quality Investigation of Environmental Conditions in Lake Pontchartrain". This sampling and analysis program was performed in 1982 and 1983. The locations and station numbers of the DEQ sampling stations are indicated on Figure C-1 in Appendix C.

Tables C-8 through C-12 in Appendix C present the results of selected heavy metals analyses in sediment samples collected for the DEQ report. With the exception of zinc, metal concentrations were consistently higher near the 17th Street Canal than at other locations.

Table C-13 in Appendix C presents total hydrocarbon content in various sediment samples collected for the DEQ report. It can be seen that the southern nearshore areas are more contaminated than offshore areas or areas of the north shore. The area just off the 17th Street Canal (Station LP04) is much more contaminated than the rest of the lake as well as the other nearshore areas.

Tables C-14 through C-18 in Appendix C present the results of selected organic chemical analyses in sediment samples collected for the DEQ report. At least 58 identifiable organic chemicals were detected in quantities that are attributable to man's input. Of this number, only six are unquestionably synthetic: polychlorinated biphenyls (PCB's) and the pesticides chlordane, nonachlor, heptachlor, and the DDT metabolites - DDM and DDE.

Of the organics identified in sediments, the predominant chemical class (both by numbers of species and in highest concentrations) was the polynuclear aromatic hydrocarbons (PAH's). This group includes chemicals

of fairly complex structure whose occurrence in ecosystems in other than low parts per billion levels (ppb) must be attributed to anthropogenic input. PAH's are generally associated with the combustion, use, and handling of fossil fuels. These compounds as a group were the most ubiquitous organics found in Lake Pontchartrain.

Another fairly ubiquitous group of organics were the phthalate esters. These chemicals are plasticizers that have many uses in chemical manufacturing. Concentration in sediments ranged from a few parts per billion to as high as 860 ppb. Nearshore areas typically exhibited markedly higher levels than offshore where concentrations rarely exceeded 2 ppb. Intermediate stations (less than two miles from shore) ranged up to levels of 10 ppb. Levels in nearshore areas along Orleans Parish were higher than along Jefferson Parish.

Four identified compounds of the fairly large class of halogenated volatile and aromatic hydrocarbons were quantified in lake samples. These included compounds such as dichlorobenzene, chloronaphthalene, and tribromoethylene. They were detected only very sporadically in the area off Orleans Parish. Their concentrations ranged from 1-20 ppb in sediments.

An important group of organic chemicals detected were the synthetic chlorinated hydrocarbon pesticides and polychlorinated biphenyls (PCB's). Overall, PCB concentrations were higher than those of any other synthetic chlorinated hydrocarbons in Lake Pontchartrain sediments. However, with the prominent exception of the station off the mouth of the 17th Street Canal, levels at all other localities were fairly low.

Mean concentration for chlordanes decreased progressively with distance from the south shore. Excluding Station LP04 off the mouth of the 17th Street Canal, mean concentrations for all other nearshore stations combined was 5.1 ppb. From this level, a nearly ten-fold decrease in mean concentration (0.6 ppb) occurred by the distance from

the south shore of the intermediate stations (1.0 to 1.8 miles). A further ten-fold decrease in combined mean concentration (0.06 ppb) was obtained by the distance of the southern offshore stations (2.75 to 4.5 miles).

A somewhat similar but less dramatic pattern was evident obtained for the DDT metabolites. From a combined mean concentration of 1.0 ppb at the nearshore stations (again excluding LP04), a five-fold decrease to 0.2 ppb was reached by the distance of the intermediate stations; but no further significant decrease occurred at the offshore stations (0.18 ppb).

3.4.2.2.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

The concentrations of the fourteen metals (thirteen priority pollutant metals and barium) in the surficial sediments of the southern shoreline of Lake Pontchartrain revealed maxima at the mouths of the outfall canals at Duncan Canal, 17th Street Canal, Bayou St. John, and IHNC during most of the sampling collections of 1982-83. With the exception of zinc, metal concentrations were consistently higher near the 17th Street Canal than at the other stations.

The existing areal restrictions imposed on shell dredgers restricts dredging operations in the nearshore areas where pollutants from anthropogenic origin are located. The areas where shell dredging is allowed are not heavily contaminated and, for the most part, sediment constituent concentrations are similar to background levels. These restrictions significantly reduce the potential for problems due to release of contaminants to the water column.

The primary effect of shell dredging on water quality would be a temporary increase in turbidity. This is discussed elsewhere in this report. Nutrients such as nitrogen and phosphorus could be temporarily increased in the area of dredging activity. However, this is not considered significant in relation to the size of Lake Pontchartrain.

There has been considerable concern that any contaminants released may biomagnify in the aquatic food web. Therefore, this topic warrants further discussion. Kay (1984) recently reviewed the literature on the potential biomagnification of contaminants in marine and freshwater food webs. Biomagnification refers to the resultant total process including bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated toxic substances increase as this material passes up through two or more trophic levels (Kay, 1984). The following discussion is based largely on the results of his review.

Pesticides and pesticide residues, nutrients, organic wastes, heavy metals, and other contaminants entering our waterways may associate strongly with particulate materials and eventually accumulate in the sediments. The presence of high levels of potentially toxic contaminants in some sediments has generated concern that shell dredging operations may cause the deterioration of the environment in the lakes. Chemical residues which persist in the environment may be absorbed by plants and animals and accumulate within their tissues to levels that are greatly in excess of the ambient concentrations in their environment. Many of these substances have no known biological function and could accumulate to levels that are detrimental to the organism itself, or to its predators.

Biomagnification may occur if the contaminant is persistent in biological systems and the food pathway is essentially linear, with the predominant energy flow from lower to higher trophic levels. Most aquatic ecosystems are rather weakly structured and do not have trophic levels as clearly defined as those in terrestrial ecosystems. Although biomagnification is well documented in terrestrial ecosystems, the

occurrence of biomagnification in aquatic ecosystems is questionable and is the topic of considerable debate. The available information suggests that mercury, particularly methylmercury, may be the only heavy metal that biomagnifies significantly within aquatic food webs. Food is also an important source of copper, zinc, and selenium, all of which are essential trace elements for animal metabolism, as well as arsenic, chromium, lead, and possibly cadmium, which are not known to have any biological functions. These metals do not appear to biomagnify, however.

Organic compounds which appear to have significant potential for biomagnification include polychlorinated biphenyls (PCB's), benzo(a)pyrene, the naphthalenes, and, possibly, a few organochlorine insecticides, such as dieldrin, endrin, kepone, and mirex. Relatively little food-chain information was available for other organic compounds, however. The data available indicate that biomagnification of contaminants in freshwater and marine food webs is not a dramatic phenomenon. Most heavy metals and organic compounds probably do not magnify over several trophic levels in aquatic ecosystems. As the biological availability of contaminants from sediments should be similar regardless of whether or not these sediments have been dredged and placed in an open-water disposal site, it appears unlikely that the open-water disposal of dredged material from shell dredging operations would have any substantial impacts on biomagnification.

Alternative 2 - No Federal Action (Permit Denial)

With the shell dredges not operating, there would be less disturbance of the bottom sediments in Lakes Maurepas and Pontchartrain. This would lessen the potential for introducing nutrients and sediment contaminants into the water column.

3.4.2.3. Sediments - Physical Characteristics

3.4.2.3.1. Existing Conditions

Bahr et al. (1980) reported on the distribution of sediments in Lake Pontchartrain during 1978 (Figure 6). The sediments in the lake are diverse and include sand, silty sand, sandy silt, sandy clay, clayey sand, clayey silt, and silty clay. Sediment types vary in different areas of the lake and vary considerably in the percentage of the lake bottom they occupy. Bahr et al., (1980) reported the following proportions for the major sediment types.

		Total
Sand	5.0%	
Silty Sand	12.2%	
Clayey Sand	4.6%	21.8%
Sandy Silt	9.3%	
Clayey Silt	19.5%	28.8%
Sandy Clay	1.8%	
Silty Clay	47.6%	49.4%
		100.0%

The Lake Maurepas sediments consist primarily of sand (about 60 to 70 percent). The silt fraction comprises about 10 to 20 percent and clay ranges from about 20 to 30 percent. These distributions were measured in samples obtained during 1983 and 1984 (Childers, 1985). Sediments in the central portion of the lake are finer than the nearshore sediments.

The bottom sediments in most of the permitted area of Lake Pontchartrain are predominantly clays and silts having moderate to high organic content. The shallow depths of Lake Pontchartrain, generally 15 feet or less, and the small tide ranges promote the dominance of wind driven circulation patterns. Wind speeds of 15 miles per hour are able to begin resuspension of bottom sediments, except in the deeper eastern portions of the lake. At speeds of 40 miles per hour, complete resuspension of unconsolidated bottom sediments occurs throughout most of the lake.

These wind speeds are exceeded on the average about 15 and 1 percent of the time. The bottom currents associated with tides are generally too slow to cause resuspension, but can keep the sediments in motion once they are resuspended by other means, e.g. wind-induced turbulence, shell dredging, and shrimp trawling.

The only location within the permitted area of Lake Pontchartrain where turbidity has been regularly measured on a long-term basis is at mid-Causeway. Typical background surface turbidity levels at this station are lowest during summer and fall and range from 0 to 7 NTU's. During the winter and spring, typical levels are between 1 and 23 NTU's. Ambient turbidity in other parts of the permitted area nearer the shorelines and mouths of tributaries is generally higher than in mid-lake. Turbidity is also relatively higher in the western portion or the lake than in the eastern portion because of the respective proximities of the major freshwater tributaries and the tidal passes.

The gaging station at the mouth of Pass Manchac would be expected to experience some of the highest background turbidity levels in Lake Pontchartrain, except during operation of the Bonnet Carre' Spillway. During the high runoff months in the winter and spring, measured turbidity levels are usually 40 NTU's or less, and average about 20 NTU's. During the remaining half of the year, turbidity levels at this station typically range between 10 and 20 JTU's.

It has been observed during open-water dredging and disposal activities that suspended sediment concentrations become greatly elevated in the immediate vicinity of the dredge intake (fishmouth) and the discharge pipe.

Field surveys of turbidity plumes from shell dredges in Lake Pontchartrain were conducted in May and August 1974 by Gulf South Research Institute (GSRI), in May and November 1983 by the Louisiana Department of Natural Resources (DNR), in September 1984 by the Louisiana

Department of Environmental Quality (DEQ), and, by Steimle and Associates, Inc., in August and December 1984.

GSRI monitored three dredged areas and control sites in west central, south central, and southwestern Lake Pontchartrain. Turbidity, total suspended solids, and a broad range of other water quality parameters were measured near the surface and bottom of the water column. Turbidity and suspended solids were sampled at distances of 50 to 2,200 feet from the operating dredge Kathy L. along radials extending outward from the center of the dredged circle at 60-degree intervals. Maximum top and bottom TSS values of 1,890 and 5,640 mg/L were measured at distances of 50 and 400 feet from the dredged circle. The maximum turbidity levels recorded were 410 JTU's (Jackson Turbidity Units) at 50 feet (surface) and 3,000 JTU's at several distances (bottom). Control site TSS values averaged 53 and 69 mg/L, respectively.

The May 1983 DNR investigation utilized three sampling boats which collected water samples before and after the passage of an operating dredge, and a fourth boat which sampled immediately behind the dredge. The reported near-dredge turbidity levels were 270 NTU's (surface) and 1,120 NTU's (bottom). Corresponding TSS values were 410 and 2,280 mg/L, respectively. The background surface and bottom turbidity levels each averaged 19 NTU's.

A DNR investigation of shell dredge activity was conducted in November 1983 in southeastern Lake Pontchartrain, but was aborted after about 4.5 hours because of high winds and waves. Maximum measured surface and bottom turbidity values of 800 and 1,000 NTU's were recorded at a station immediately behind the dredge Sheldrake after one hour of observations. Corresponding maximum measured TSS values were 800 and 1,300 mg/L. Background surface and bottom turbidity averaged 35 and 58 NTU's, respectively.

In May 1984, DEQ monitored turbidity levels and other water quality parameters near an operating shell dredge in southeastern Lake

Pontchartrain. The turbidity plume was sampled at a stationary site periodically from 30 minutes before to 6 hours after the passage of a shell dredge at time zero. Surface turbidity quickly rose from an ambient level of 6 NTU's (Nephelometric Turbidity Units) to 2,520 NTU's as the dredge passed the site. At 30 minutes after time zero, the surface turbidity had decreased to 30 NTU's, and further decreased to a stabilized value of 10 NTU's. The bottom turbidity levels rose from 13 NTU's (background) to 6,000 NTU's as the dredge passed, but the maximum bottom turbidity observed (at 30-min intervals) was 11,600 NTU's at one hour after dredge passage. Subsequent samples at 1.5, 3, and 6 hours after time zero measured 800, 99, and 30 NTU's, respectively. Thus, the bottom turbidity was still slightly elevated five hours after the surface plume had stabilized.

In July 1984, turbidity generated by the dredge A. W. Shucks in central Lake Pontchartrain was monitored by Steimle and Associates, Inc. Samples at distances one-half mile or greater from the dredge revealed a maximum surface turbidity of 46 NTU's and a maximum bottom turbidity of 507 NTU's. Similar measurements at one-fourth mile or more from the dredge Chickasaw the same day in the central part of the lake showed maximum observed surface and bottom levels of 96 and 1,540 NTU's, respectively.

The above-named dredges, with 38,500 gpm discharge capacities, and the Avocet, with a 32,000 gpm capacity, were monitored in southwestern Lake Pontchartrain for turbidity and TSS in December 1984. Maximum observed surface turbidity levels were 113, 62, and 42 NTU's, and the maximum bottom values were 120, 330, and 420 NTU's. Corresponding maximum observed TSS concentrations were: surface - 247, 382 and 117 mg/L, and bottom - 368, 720, and 1,870 mg/L. All of the maximum surface and bottom values were recorded at distances of 0.15, 0.45, and 0.00 mile from the sites of dredge passage over the transect, which were the minimum distances that were sampled. Elapsed times from dredge passage were 5, 15, and 0 minutes.

It can be generally stated that the surface turbidity plumes begin as highly concentrated masses of sediment and shell fragments at or near the water surface. Turbulence in the immediate mixing zone near the discharge promotes the dispersion and advection of the dredged sediments in the direction of prevailing currents. In the case of the Sheldrake, all except a small percentage of the finer sediments settle quickly and do not contribute to upper water column turbidity.

Computer simulations of the physical behavior of sediments discharged from a propeller-driven shell dredge indicated that flocculation of the finer sediments is initially prevented by the momentum of the propeller wash, which entrains all but a small percentage of the discharged solids in a horizontal jet behind the moving dredge. As the jet velocity decreases away from the dredge, the rates of gravity settling of the larger sediment particles gradually approach the settling rates experienced initially by the Sheldrake discharges. Except under nearly fresh conditions, flocculation of clays and the silts will occur, although probably at a slower rate than normally occurs in conventional hydraulic dredging because of the induced dispersion of the sediment particles.

The mass of deposited material is most commonly termed fluid mud. The initial dispersion of the dredged material over a wide area ensures that the thickness of the fluid mud layers will be smaller than one inch near the dredge, and considerably below 0.1 inch at distances of 100 feet or more. The only shell dredge that is not propeller-driven (the Sheldrake) produces a relatively thick mound or ridge of fluid mud along its path. Some of the discharged sediments fall directly into the dredged trench, but a much larger proportion settles outside of the trench.

Since the upper fluid mud layers are relatively less dense, they are initially subject to lateral movement by bottom currents and gravity to lower elevations of the lake bottom. As these upper layers migrate they gradually densify and become increasingly resistant to further movement by tidal currents. It is estimated on the basis of computer

simulations (USCE, 1987) that the fluid mud layer thickness is about 0.5 to 0.8 inch over a distance of 50 feet from the dredge path one hour after dredging occurs. The actual thicknesses of fluid mud at particular times and locations are dependent on many factors, including grain size distribution, tidal current speed and direction, intermittent wave turbulence, and possibly additional dredge passages over a previously dredged area.

No direct measurements of fluid mud thickness changes with time have been made in Lake Pontchartrain. It is generally recognized that about 97 percent or more of the sediment solids discharged into open water by a clamshell dredge settle to the bottom within short time periods and distances where they accumulate as layers of fluid mud overlying the denser bottom sediment. The upper, low-density layers remain subject to hydrodynamic forces, and are moved along the bottom by the prevailing currents until their density becomes sufficient to resist further lateral movement.

The process of self-consolidation of the fluid mud begins when its density becomes about 200 g/l (Migniot, 1986). Because of the high solids concentration and the degree of particle interaction that is developed, the high-density layers of fluid mud tend to move more slowly than the low-density mud. As the consolidation process continues, interstitial water is squeezed out by the weight of overlying material, and the fluid mud becomes much more resistant to lateral movement (Einstein and Krone, 1962). Beyond a certain density, the force of the normal tidal currents becomes too weak to move the material, and it begins to regain its former pre-dredged condition through continued self-consolidation under its own weight.

The time required for complete restoration of the deposited material to its former state is unknown. Intermittent disturbances and resuspensions of the uppermost layers by wind-wave turbulence may retard the eventual densification for extended time periods, but the bulk of the fluid mud material will become relatively stable within minutes to hours

of its initial deposition. It must be remembered, however, that the nearsurface sediments of Lake Pontchartrain never become sufficiently consolidated to be immune to resuspension by wind waves, except perhaps in the extreme eastern reaches near the passes to Lake Borgne. Their inherent degree of instability makes it difficult, if not impossible, to define a typical state of consolidation of Lake Pontchartrain surface sediments.

Shell dredging has been prohibited in Lake Maurepas since 1984, when it was concluded by the DEQ that sustained higher than normal levels (above State standards) of turbidity and suspended sediment were directly attributable to the dredging activity. Aerial surveillance of the lake during May and June 1983 had revealed persistent, lakewide extreme turbidity levels. Lake Maurepas continued to be monitored in subsequent months to determine recovery time to normal conditions and to develop a data base of seasonal variations of turbidity and other water quality parameters.

After restricting activity to one dredge throughout December 1983, rather than the three dredges previously allowed to operate, it was determined that lake-wide turbidity levels remained extremely high and far greater than would be expected from natural hydrometeorologic conditions. Mean turbidity levels of 200-300 NTU's, and maximum levels of 600-950 NTU's were recorded during dredging. The normal, without-dredging turbidity in the lake is believed to be less than 50 NTU's.

In August 1984, the Water Pollution Control Division of DEQ reported that even when one dredge was operating for a brief time period, unacceptable water quality degradation occurred, unlike in Lake Pontchartrain which was capable of reasonably rapid recovery. It was therefore recommended that shell dredging be prohibited in Lake Maurepas until the industry could demonstrate that generation of sustained high turbidity and suspended sediment levels could be precluded.

The reasons given by DEQ for the distinct differences between water quality effects in the two lakes were: the relatively smaller size and depth of Lake Maurepas; zero or very low salinity levels in Lake Maurepas; and likely differences in sediment characteristics and deposition patterns in the lakes. Although the data and analyses were not so thorough as to be completely conclusive regarding the specific causes for higher Lake Maurepas turbidity, it appears obvious that shell dredging operations are primarily responsible.

Additional information concerning physical characteristics of sediments, including turbidity, suspended sediments, and fluid mud is presented in Appendix C.

3.4.2.3.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

The most obvious impact of shell dredging is the highly visible surface turbidity plume that is generated. Near-surface turbidity plumes are caused by clay and fine silt in the immediate vicinity of the discharge. Except under fresh or nearly-fresh water conditions, flocculation occurs and the composition of suspended near-surface sediments soon becomes limited to clay particles as the silt and flocculated clay begin to settle out.

The shape, size, and rate and direction of horizontal movement of the turbidity plume beyond the discharge location rapidly become a function of the currents and of turbulence within the water column. For a brief time after discharge, the dynamic energy imparted by the propeller wash (if present) and the speed of the moving dredge are the dominant factors influencing the characteristics of the turbidity plume. The initial momentum imparted to the plume by the moving dredge gradually diminishes with time at a rate governed by the hydrodynamic regime. Water column turbulence prolongs the suspension times of discrete sediment particles,

but also increases the frequency of interparticle collisions, thus promoting floc formation and accelerated settling rates. Higher current speeds produce a longer, more narrow turbidity plume than slow currents, which produce a more rounded plume that eventually occupies a larger area of the lake. The migrating plume proceeds outward in the general direction of the currents, and slowly downward through the water column until it impacts the lake bottom, at water depths normally between 10 and 16 feet.

Only during high runoff periods during the late winter and spring months are northwestern lake salinity levels likely to fall much below 1.0 ppt. During these periods, flocculation rates will likely be reduced and turbidity will be more persistent in the water column. Mideastern lake salinity would not be expected to fall below 1.0 ppt except during Bonnet Carre' Spillway operations. During periods of low salinity and high turbidity, certain aquatic organisms may already be stressed and increases in turbidity and associated water quality problems as a result of dredging may compound this stress.

Regarding short term effects, it can be acknowledged that shell dredging causes greatly elevated suspended solids concentrations and turbidity levels near the dredge, which typically become reduced to respective ranges of 1,000 to 2,000 mg/L and 500 to 1,000 NTU's within a distance of about 500 feet from the dredge. Except under infrequent low salinity conditions, flocculation of the finer clays will occur, causing gravity settling. The turbidity plume's size and shape beyond the immediate vicinity of the dredge are controlled by hydrodynamic conditions in the lake. Maximum turbidity levels within the plume tend to diminish exponentially with horizontal distance from the discharge site, and also occur gradually lower in the water column as gravity settling of the flocculated clays continues. Maximum areal limits of the plume are dependent on prevailing currents and water depths.

Long-term turbidity impacts from shell dredging and the other identified major influences are generally much more difficult to assess.

The post-dredged sediments are initially less dense than before dredging and are therefore more easily resuspendable from that standpoint than the pre-dredged sediments. The fact that the entire lake bottom is intermittently disturbed by wind wave turbulence is undoubtedly a very important factor influencing the rate of sediment recovery to pre-dredged conditions.

The average tributary and Bonnet Carre' Floodway inflows to Lake Pontchartrain have been significantly higher since the early 1970's than during the previous 15 to 20 years. It is believed that the resultant increased supply of alluvial sediments to the lake during the more recent period has to some degree been responsible for increased average lakewide turbidity levels since the 1950's and 1960's. It is also believed that the ongoing activities of shell dredging and shrimp trawling have each been partially responsible for the overall long-term turbidity increases, with shell dredging having somewhat more of a total impact than trawling. The intensity of shell dredging increased greatly during the 1960's and 1970's, but has gradually declined in intensity since the mid-1970's.

The phenomenon of fluid mud generation by open-water dredging and disposal activities has been mentioned previously and is discussed in detail in Appendix C. Inferences have been drawn about the likely extent and rates of movement of fluid mud along the bottom in Lake Pontchartrain relative to other water bodies where field research has been conducted. Although it is acknowledged that most of the discharged sediment does not immediately return to the dredged trench, it is nevertheless stated that, within reasonable periods of time, wave turbulence and tidal currents tend to smooth the bottom contours by moving the less dense, unconsolidated upper layers of deposited material to lower elevations in adjacent areas. Also, the continuous forward motion of the dredges assures that the deposited material does not become initially concentrated as thick mounds in small areas.

In summary, primary impacts to the lakes resulting from physical disturbance of the bottom sediments by shell dredging include creation of a layer of fluid mud, short-term increases in levels of total suspended sediments and turbidity, and a potential contribution to the apparent long-term increase in lakewide turbidity.

Shell dreding generates a thin layer of fluid mud along the dredge path that spreads laterally in response to gravity and bottom currents until its density becomes sufficient to resist further movement. This layer is estimated to be less than one inch thick on the average within 50 feet on each side of the dredge, and less than 0.1 inch thick at distances of 100 feet or more from the dredge within one hour after discharge.

Regarding short-term turbidity effects, it is documented that shell dredging causes greatly elevated suspended solids concentrations and turbidity levels near the dredge. GSRI (1974) conducted a study and reported that turbidity returned to ambient conditions near the water surface at a distance of approximately 1,000 feet. It is acknowledged, however, that the shape and areal extent of the turbidity plume varies depending on the speed and direction of the moving dredge and hydrometeorological conditions. Surface turbidity normally decreases to near background levels very rapidly after passage of the dredge, particularly if salinities are above 1.0 ppt. Under fresh or nearly fresh conditions, turbidity is more persistent. Since only about 1 percent of the total area of Lake Pontchartrain is affected by this short-term turbidity at any given time, it is not considered significant.

The extent to which shell dredging has contributed to the apparent long-term increase in lakewide turbidity levels is unknown. It is reasonable to assume that the less consolidated sediments that occur for a period of time following dredging activities are more susceptible to resuspension by wind and wave activity, thereby contributing to increased turbidity levels. However, a variety of other factors have also

contributed to the long-term increase in turbidity. The fact that turbidity levels prior to the advent of shell dredging are unknown, combined with the influences of a variety of other factors that affect turbidity, make it impossible to quantify the impacts of shell dredging on long-term turbidity increases.

Shrimp trawling occurs seasonally in Lake Pontchartrain and is regulated by LDWF. This activity disturbs lake bottom sediments on a scale comparable to shell dredging, but the fact that trawling affects only the relatively unconsolidated surface sediments means that a much smaller total volume of solid material is affected than by dredging. It is therefore concluded that the overall impacts on turbidity, especially near the water surface, is greater for shell dredging than for shrimp trawling. A discussion of the relative impacts of these two activities appears in Appendix C.

It has been stated numerous times in this EIS that shell dredging may contribute to the apparent overall long-term turbidity increase in Lake Pontchartrain, but the extent of the contribution is unknown. Regulation 40 CFR Part 1502.22 provides an approach to the problem of incomplete or unavailable information in an EIS. In such instances, the agency should always make it clear that information is lacking. According to 1502.22(b), if the information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining are exorbitant or the means to obtain it are not known, the agency shall include within the environmental impact statement:

"(1) A statement that such information is incomplete or unavailable."

"Incomplete information" refers to information which the agency cannot obtain because the overall costs of doing so are exorbitant. In the case of shell dredging, separating its contribution to the long-term increase in turbidity in Lake Pontchartrain from the contributions of the

many other factors that can also cause turbidity increases would be exceedingly difficult. It is highly unlikely that the impacts of shell dredging could be meaningfully quantified and the costs of any efforts to do so would be exorbitantly expensive in terms of both time (years) and money (millions of dollars). "Unavailable information" refers to information which the agency cannot obtain because the means to obtain it are not known. Although a number of people have pointed out that the studies should be done to quantify the impacts of shell dredging on long-term turbidity, no one has proposed any methodologies to accomplish this task. Any meaningful attempt to do so would require that long-term studies (5-10 years) on a lakewide basis be conducted both with shell dredging in place and with shell dredging prohibited. Even then, the aperiodic magnitudes of the other factors contributing to turbidity in the lake would complicate matters.

"(2) A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable adverse impacts on the human environment."

The primary areas of relevance regarding long-term increases in lakewide turbidity are impacts to phytoplankton production, grassbeds, and benthic algae which contribute to the primary productivity of the lake. Increased turbidity limits light penetration and decreases the depth of the photic zone which ca adversely impact production of phytoplankton, grassbeds, and benthic algae. Phytoplankton contributes to the productivity of the system by providin; a source of food for zooplankton and a variety of nektonic organisms. In addition, the bodies of dead phytoplankters fall to the bottom where they are consumed by benthic organisms. Grassbeds function as valuable spawning and nursery areas for a variety of finfish and shellfish. Benthic algae also serves as a source of food for various aquatic organisms. Increased turbidities may have played a role in their decline. Although the impacts of shell dredging cannot be quantified and separated tr m the other factors that

have also contributed to long-term increases in turbidity, it is acknowledged that shell dredging may adversely impact the productivity of phytoplankton, grassbeds, and benthic algae.

"(3) A summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment."

Credible scientific information regarding the impacts of turbidity on the human environment has been summarized in the EIS and accompanying appendixes.

"(4) The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community."

Item (4) requires that the agency use sound scientific methods to evaluate the potential impacts. As discussed above, it is apparent that quantification of the contribution of shell dredging to long-term turbidity cannot be accomplished. However, the potential impacts have been addressed using information available in the literature. This approach is commonly used and generally accepted in the scientific community.

Alternative 2 - No Federal Action (Permit Denial)

Total restriction of shell dredging in Lake Pontchartrain would relieve the lake of the abnormally high levels of turbidity and suspended sediments that characteristically occur at and near operating dredges. The absence of shell dredging for an extended period may lower future turbidity levels.

The absence of intermittent bottom sediment disturbances from shell dredging would mean that lake sediments would tend to gradually revert toward their former, pre-dredging state.

3.5. BIOLOGICAL ENVIRONMENT

3.5.1. **Botanical Resources**

3.5.1.1. Grassbeds

3.5.1.1.1. Existing Conditions

Submerged grassbeds commonly occur in inland and coastal waterbodies and are important aquatic habitats. Species composition varies from one location to another due to differences in environmental conditions. The value of estuarine grassbeds has been well documented. The primary grass beds in the Lake Pontchartrain area presently occur along the northeastern shore, in Lake St. Catherine, and off South Point and Point aux Herbes (Figure 7). However, in past years, grassbeds occupied large areas along the southern shore of the lake. No grassbeds have been reported in Lake Maurepas.

Several studies have been conducted regarding submerged aquatic vegetation in Lake Pontchartrain. These studies have been summarized in Appendix D. Suttkus et al. (1954) provided the first report of submerged aquatic vegetation in Lake Pontchartrain. They found four species of submerged aquatics in their study, including Eleocharis sp. (spikerush), Ludwigia sp. (waterprimrose), Ruppia maritima (widgeongrass), and Vallisneria americana (wildcelery).

Perret et al. (1971) estimated that the grass beds on the northern shore of the lake covered about 20,000 acres, but this was not based on detailed investigation. Montz (1978) published a report which accurately described the distribution, composition, and relative abundance of the submerged vegetation in Lake Pontchartrain. In addition to the previously reported species, he noted Najas guadalupensis (southern naiad) throughout the north shore area. He also reported Potamogeton perfoliatus (pondweed) to be abundant off Point aux Herbes. Montz

calculated that about 2,000 acres of waterbottoms on the northern shore were vegetated with submerged aquatics.

Thompson and Verret (1980) recorded occurrence of submerged aquatic vegetation while conducting a study of nekton in the lake. In addition to previously noted species, they encountered Cabomba caroliniana (fanwort), Myriophyllum spicatum (Eurasian watermilfoil), and Ceratophyllum demersum (coontail).

Mayer (1986) conducted a detailed study of the grassbeds in Lake Pontchartrain. The largest acreage of grassbeds in the lake was on the northern shore and consisted of wildcelery, widgeongrass, Eurasian watermilfoil, and southern naiad. These grassbeds extended offshore an average of about 100 meters, with a maximum offshore extension of about 350 to 400 meters. Total areal coverage of submerged aquatic vegetation in Lake Pontchartrain was about 981 acres. Approximately 80 percent occurred on the northeastern shore between Green Point and Big Point (Figure 7).

The areal extent of grassbeds decreased approximately 50 percent between 1973 and 1985 (Mayer, 1986). Significant changes in the distribution of submerged aquatics has occurred in several areas of the lake. It also appears that the dominant grassbeds in the Lake are not found at the same depths as they were historically. The species composition of grassbeds has also changed dramatically in the lake. There has been widespread colonization of Eurasian watermilfoil, an introduced species. While the dominant native species have experienced significant reductions in abundance, Eurasian watermilfoil has expanded its range in many parts of the lake.

The potential causes of the documented decline in acreage and changes in species composition of the grassbeds in Lake Pontchartrain are varied, complex, and more than likely synergistic in effect. Mayer (1986) discussed these possible causes in some detail (Appendix D). Many of

these issues are also discussed in the Cumulative Impact Section (Section 3.8) of this EIS.

3.5.1.1.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Turbidity has been identified as having the potential to adversely impact grassbeds. Although turbidity in the lake arises from a variety of natural causes, including riverine input and wind activity, some of man's activities also contribute to the turbidity. These include operation of the Bonnet Carre' Spillway, urban and agricultural runoff, man's development of the wetlands surrounding the lake, channel dredging, shrimping, and shell dredging.

Discharges from the shell dredges operating in Lake Pontchartrain create a turbidity plume in the immediate area of the operating dredges. Detailed discussions concerning the levels of turbidity and magnitude of the plumes are presented in Section 3.4.2 of this EIS and Appendix C. The areal extent of these plumes varies depending on the salinity, wind, and tidal action in the vicinity of the dredge at any given time. Based on studies conducted by the Gulf South Research Institute (1974), turbidity returned to ambient conditions near the water surface at a distance of approximately 1,000 feet. The areas in the lake where grassbeds occur are well within the one mile protected zone where shell dredging is prohibited. Based on Mayer's recent grassbed surveys, the maximum lakeward extent of submerged aquatic beds is about 1,150 to 1,300 feet. Using a conservative figure of 0.5 miles (2,640 feet) for the distance affected by an average dredge plume, the outermost extension of the grassbeds would be about 0.25 miles inland of the plume, even if the dredge was operating immediately adjacent to the restricted zone. It is not likely that the turbidity plume would have any significant impact on the grassbeds, particularly in light of the fact that the major concentrations of grassbeds occur well within the 1,150 to 1,300-foot lakeward limit. Additionally, the dredge plumes are temporary in nature,

and with the zoning restrictions imposed upon the industry by the LDWF, shell dredging does not occur continuously in the zones adjacent to the primary grassbeds anyway. It should be pointed out that shell dredging activities in the lake began about 20 years before the first reported turbidity measurements were taken.

In summary, increased turbidity has been implicated as one of the potential causes for the decline of grassbeds in the lake. Shell dredging is only one of many activities that may have contributed to this increase, and it appears that the turbidity plume created by the dredges does not have any immediate adverse impact on the grassbeds. With the current state of knowledge, it is not possible to quantify the impacts of shell dredging on long-term turbidity increases in Lake Pontchartrain.

Alternative 2 - No Federal Action (Permit Denial)

There has been some increase in turbidity in Lake Pontchartrain over the last 30 years and it is possible that this increase has adversely impacted the grassbeds. Shell dredging is one of several factors that may have contributed to that increase. Under the No Action Alternative, shell dredging activities would cease, thereby eliminating the possibility for any dredge-induced impacts to the grassbeds.

3.5.1.2. Phytoplankton

3.5.1.2.1. Existing Conditions

Several studies have been conducted regarding the phytoplankton of Lake Pontchartrain. Suttkus *et al*. (1954) reported *Anabaena*, *Chaetoceros*, *Coscinodiscus*, *Scenedesmus*, *Nitzschia*, *Synedra*, and *Thalassiothrix* as the most common phytoplankters found. Darnell (1961) listed *Chaetoceros* and *Coscinodiscus* as the most dominant forms in a study he conducted from February 1954 through May 1955. These are surface-floating diatoms which survive well in relatively turbid environments. Stern and Stern (1969) reported 37 taxa of phytoplankton from a

study conducted from November 1968 through July 1969. The dominant phytoplankter during this period was Coscinodiscus, although it was periodically replaced in dominance by Chaetoceros and Sphaerocystis. It is not unusual for genera of phytoplankters to shift roles of dominance, depending upon environmental conditions. Stone et al.(1980) investigated the distribution and abundance of phytoplankton in Lake Pontchartrain in 1978. Sixty-four phytoplankton taxa were recorded in this study. Green algae were dominant, comprising about 54 percent of the taxa. Diatoms were not identified to genus and species, but two taxa of diatoms were found during the study. Coscinodiscus, Chaetoceros, or both were likely represented in these diatoms. No published information is available concerning the phytoplankton in Lake Maurepas.

Phytoplankton constitutes an important component of many aquatic food webs. Phytoplankters are consumed in the water column by various aquatic organisms and the dead bodies of phytoplankters fall to the bottom and contribute to the detrital layer that is also consumed by various aquatic organisms. They are primary producers that utilize inorganic nutrients, water, and carbon dioxide to synthesize organic matter through photosynthesis. During this process, oxygen is produced and released into the system. The source of energy for photosynthesis is solar energy. Phytoplankton in Lake Pontchartrain is consumed by the large copepod, Acartia tonsa, and other zooplankton. Anabaena, although seasonal in occurrence, comprised about 80 percent of the ingested material of striped mullet and menhaden (Darnell, 1954).

3.5.1.2.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Since phytoplankton production is dependent upon solar energy to provide energy for photosynthesis, the depth of light penetration into the water affects the level of production. Therefore, turbidity can limit primary production by reducing phytoplankton production. Detailed

information concerning turbidity caused by shell dredging activities is presented in section 3.4 of this EIS as well as in Appendix C. Numerous studies have been conducted to assess the impacts of turbidity that results from various types of dredging, including shell dredging.

The impact of turbidity on primary productivity depends largely on the duration of turbidity. Most of those who have studied the problem have concluded that reduced water transparency due to dredging operations is of relatively short duration (Stern and Stickle, 1978). In the case of shell dredging, the area of increased turbidity is localized and the turbidity is of short duration. The duration and areal extent of the turbidity plume resulting from shell dredging activities varies considerably depending upon salinity and hydrometeorological conditions. However, turbidity generally returns to ambient conditions within about 1,000 feet of the dredge. Even if turbidity prohibited phytoplankton production in a one square mile area around the dredge, only about 0.16 percent of the total area of the lake would be impacted. With all seven dredges operating, only about 1.10 percent of the total area of the lake would be affected at any given time. It should be pointed out that phytoplankton in the Lake Pontchartrain area are more abundant in nearshore areas particularly where rivers, bayous, or outfall canals enter the lake, than in the open waters farther from shore. This is probably due to the influx of nutrients in these areas. Dow and Turner (1980) reported that primary production was usually highest near the southeast shoreline near New Orleans and its suburbs. They found high plankton biomass at the mouths of the Tchefuncte and Tangipahoa Rivers and off Pass Manchac. Stone et al. (1980) reported that phytoplankters are significantly more abundant in the marshes surrounding Lake Pontchartrain than in the lake itself.

It does not appear that short-term turbidity resulting from shell dredging activities has any significant impact on phytoplankton and primary in Lake Pontchartrain. The impacts are localized and temporary and affect a very small percentage of the lake at any given time. However, studies have shown that shell dredging in Lake Maurepas causes

lakewide, persistent elevated levels of turbidity. Impacts of turbidity on phytoplankton production in Lake Maurepas would be significant and much more severe than in Lake Pontchartrain.

The preceding discussion concerns short-term impacts to phytoplankton related to turbidity. As previously noted in the discussion on grassbeds, it is believed that shell dredging may be one of the factors which is causing an apparent long-term increase in overall lake turbidity. However, since turbidity levels in the lake prior to the advent of shell dredging are unknown and many other factors have also influenced the long-term increase in lakewide turbidity, it is not possible to quantify the impact of shell dredging on the long-term turbidity increase.

Alternative 2 - No Federal Action (Permit Denial)

Under the No Action Alternative, shell dredging activities would cease. The temporary, localized impacts to phytoplankton and primary productivity as a result of shell dredging would be eliminated entirely and there would be no contribution to the long-term turbidity increase.

3.5.2. **Zoological Resources**

3.5.2.1. Benthos

3.5.2.1.1. Existing Conditions

Numerous studies have been conducted concerning the benthic communities of Lakes Pontchartrain and Maurepas. These are discussed generally in this EIS and in more detail in Appendix D.

The first substantial information concerning the benthos of Lake Pontchartrain was gathered during surveys conducted from 1953 to 1955. Darnell (1979, Unpublished Manuscript) has summarized this information. Sixty-seven species of benthic invertebrates were collected including

sponges, coelenterates, ctenophorans, bryozoans, annelids, mollusks, and arthropods. Mollusks constitute a very important component of the benthic community of the lake. R. cuneata is the mollusk that primarily supports the shell dredging industry and is the subject of considerable discussion throughout this EIS. Five species of gastropods were encountered in Lake Pontchartrain. Two gastropods, Probythinella louisianae and Texadina sphinctostoma, were widely distributed throughout the lake. Their numbers varied from 12.0 to 4,960/m2. Six species of pelecypods (bivalves) were found. The dominant bivalve in most of the lake was R. cuneata. In most areas of the lake, densities of R. cuneata larger than 20 mm were consistently above 100/m2 (Figure 8).

Fairbanks (1963) investigated R. cuneata populations in two limited areas in Lake Pontchartrain, one area on the northern shore of the lake and one area on the southern shore. Information on gonadal development was also obtained. Fairbanks reported that no clams less than 23.75 mm contained recognizable gametes and he suggested that clams larger than this represented potentially sexually mature adults.

Fairbanks estimated the density of adult clams from the north shore stations to be 24.54/m2. On the south shore the density was only 2.69/m2. The mean density for juveniles (<23.75 mm) from the north shore stations was 1,807.1/m2. On the south shore the mean density of juveniles was 1,887.5/m2.

Tarver (1972) sampled R. cuneata populations with a modified eighteen-inch oyster dredge throughout Lakes Pontchartrain and Maurepas to determine their occurrence, distribution, and density. Higher concentrations of R. cuneata were found around the edges of the lakes, with not many clams at the stations located more than a mile offshore.

Dugas et al. (1974) sampled the molluscan communities of Lakes Pontchartrain and Maurepas in 1972. Eight species of pelecypods and the two dominant species of gastropods were found. A total of 4,127 R.

cuneata from 2 to 5 mm composed approximately 77 percent of the total R. cuneata catch in the study. Dense populations of up to 1,847 clams/m2 occurred near the shoreline of Lake Pontchartrain. R. cuneata in the 6 to 10 mm size range were much less abundant than the 2 to 5 mm group, occurring in only 29 percent of the total samples. Rangia in the 11 to 15 mm size range were scattered in distribution and not very abundant. R. cuneata greater than 16 mm were not found in areas that had been continually dredged. They were most abundant in Lake Pontchartrain around the shorelines and were also absent from the eastern lobe of the lake. The highest densities of this size range were found in Lake Maurepas.Of the two gastropods taken in the study, Texadina sphinctostoma was present in 89 percent of the samples taken in Lake Pontchartrain. None were taken in Lake Maurepas.

Tarver and Dugas (1973) sampled R. cuneata with a modified oyster dredge on a monthly basis at 15 stations throughout Lakes Pontchartrain and Maurepas. A total of 80,644 R. cuneata were taken at the 15 stations, an average of 5,376 per station.

Clams were particularly abundant near the shoreline and where tributaries enter the lakes. The highest densities of clams were found in the western portion of Lake Pontchartrain, and dense populations of clams were also found in Lake Maurepas.

GSRI (1974) sampled benthos at 20 stations in Lake Pontchartrain and two in Lake Maurepas. Dominant organisms included R. cuneata and two small gastropods. The mean density of P. louisianae found at the 20 baseline stations in Lake Pontchartrain was 4,055/m2. T. sphinctostoma were found in a mean density of 776/m2 and R. cuneata occurred at an average density of 125/m2. The R. cuneata were not segregated according to size.

Bahr et al. (1980) conducted a macrobenthic survey of Lake Pontchartrain. Twenty four species or related groups were collected at

85 stations, with the six most abundant species comprising about 93 percent of the total. The size of the R. cuneata taken in the study varied considerably between the shoreline and the open lake. Shallow areas were dominated by large R. cuneata (>30 mm), whereas clams larger than 10 mm were very rare at the 85 open lake stations.

Roberts (1981) conducted studies of the benthic communities in Lake Pontchartrain using 10 stations along a transect in the northeastern portion of the lake. The stations ran in a southwesterly direction from just north of Goose Point out into the restrictive corridor along the Causeway. A total of 23 macrofaunal and 14 microfaunal taxa were collected at the 10 stations.

Sikora et al. (1981) conducted a study concerning the environmental effects of clam shell dredging. The primary purpose of this study was to compare the sediments and benthic communities in a dredged and a control area. An experimental dredging station (DX) and a control station (DC) were established at about mid-lake within the restricted zone along the Lake Pontchartrain Causeway (Figure 9). The results of this study are discussed later in the impacts section.

Sikora and Sikora ([illegible]) characterized the benthic community of Lake Pontchartrain. [illegible] stated that one of the most significant faunal changes in the lake was the loss of larger R. cuneata (>20 mm) from the open lake. They took [illegible] box core samples during their two-year study. Only [illegible] R. cuneata over 30 mm and 33 R. cuneata in the size range of 20-30 mm were collected in these samples, representing a mean density of 0.19/m2 and 0.62/m2, respectively. During the two-year period, the overall mean density for all sizes of R. cuneata was 3,256.5/m2; however, clams over 20 mm equaled less than 0.03 percent of the density. R. cuneata in the size range 10-20 mm accounted for less than one percent of the overall mean density.

Poirrier et al. (1984) evaluated the benthic community of southern Lake Pontchartrain. Fifty-six taxa were collected during the study. R.

cuneata abundance were obtained for four size classes in this study (2-10, 10-20, 20-30, and >30 mm). As reported in the other studies, large numbers of small clams were found, with larger clams being far less abundant. In this study, the number of gastropods was considerably lower than reported by Sikora and Sikora (1982).

Childers (1985) conducted a baseline study of water quality and faunal communities in Lake Maurepas, including components of the macrofaunal community. A total of 21 taxa of invertebrates were identified. Rangia cuneata accounted for about 29 percent of the organisms. Six taxa made up 87 percent of the organisms counted. In addition to Rangia, chironomids, polychaetes, oligochaetes, and the hydrobiid gastropods P. louisianae and T. sphinctostoma contributed to this percentage. In general, these benthic organisms were more abundant at nearshore stations than in mid-lake. Due to their relatively large size, Rangia dominated the biomass of the benthos. The two species of hydrobiid snails were widely distributed and occurred in substantial numbers throughout the year. Schexnayder (1987) produced an M.S. Thesis on the macrobenthos of Lake Maurepas. His report is based largely on the benthic data collected during the Childer (1985) study. Both Childers and Schexnayder reported that the most striking observation seen from this study is the dearth of organisms at mid-lake sites.

Taylor (1987) conducted an investigation to assess the recovery of the benthic community over a longer period of time at Sikora's stations DC and DX. Taylor Biological Company sampled these stations in a manner similar to that used by the Sikoras to ensure compatibility of the data. Sampling was conducted on September 9 and 10 and November 12, 1986. Both sediment and benthic samples were collected. The primary purpose of the study was to resample the macrobenthos at Sikora's DC and DX stations, and compare the resulting data to findings they presented from periodic sampling, before and after experimental shell dredging, between 1978 and 1981. The results of this sampling have been statistically compared with data collected by the Sikoras and submitted to the New Orleans District in a January 28, 1987 report entitled "Shell Dredging

Reevaluation and Sediment Study - Lake Pontchartrain, Louisiana." The results of this study are discussed in the following benthic impacts section.

3.5.2.1.2. Impacts and Alternatives

Alternative 1 - Renew Permits With Existing Conditions

In order to discuss the impacts of shell dredging on benthos, it is necessary to understand the areal extent of direct bottom disturbance caused by dredging activities and to put these figures in perspective. Calculations showing the potential areas covered by dredging in Lakes Maurepas and Pontchartrain are presented in Appendix D.

It takes about 4.0 years for the dredges to directly disturb an area equivalent to the total permitted area in Lake Pontchartrain. In any given day, the dredges directly disturb an average of 0.039 percent of the total lake bottom.

It takes about 1.8 years for the dredges to directly disturb an area equivalent to the total permitted area in Lake Maurepas. In any given day, the dredges would directly disturb an average of 0.11 percent of the total lake bottom.

It is important to note that these figures represent the area that can be covered. However, in actuality, some bottom areas have been disturbed repeatedly, while others have been dredged less frequently, or possibly not at all.

It appears that shell dredging is a fairly inefficient operation in terms of harvesting all of the shells from the area over which the fishmouth passes. If it were highly efficient, shells would not still be harvested in the quantities that they are today - they would have been harvested to a level below economic feasibility some years ago. However,

it is apparent that the shell resource is declining and there is not any significant recruitment of large clams to the resource. Although beds of large, live Rangia are still encountered, the number of live clams harvested has decreased dramatically. The shell dredging industry has estimated that the life of the industry, based on an average annual harvest of 3 million cubic yards, is about 17 to 25 years.

Numerous theories for the decline of large Rangia have been promulgated and are reviewed in Appendix D. It has been noted in several of the investigations that certain size classes of Rangia are missing or entirely disappear during the course of a year-long study and that the numbers of Rangia in various size classes decrease dramatically with increasing size. It has been well documented that a sudden change in parameters such as salinity or temperature induce spawning. Larval stages have been shown in the laboratory to require salinities of 2-10 ppt. Once they have settled after about 6-7 days, juvenile clams tolerate a wider range of salinities. Populations of single size classes have been reported to indicate conditions suitable for spawning and recruitment occurring over long time intervals, i.e., years (Thompson and Fitzhugh, 1985). This phenomenon has been noted particularly at the 2-10 ppt salinity limits for the larvae (Hopkins et al., 1973). Tarver and Dugas (1974) reported that the 27 specimens they collected in the 11-16 mm size range represented only 1 percent survival from the 4,127 clams collected in the 2-5 mm group. The highest density of clams >16 mm (583/m2) in Lake Pontchartrain was in grid 80 near the mouth of the Bonnet Carre' Spillway. The adjacent grid 81 had the highest density of Rangia in the 6-10 mm range, indicating that spawning, survival, and growth occurred in that general area of the lake. However, in many other areas of the lake, high densities of clams of successive size ranges were not encountered. Other sampling efforts report similar findings.

Annual growth increments for the first 3 years of life for two populations of Rangia in Lake Pontchartrain were estimated to be 15-20 mm the first year, 5-9 mm the second year, and 4-5 mm the third year

(Fairbanks, 1963). As with most organisms, increments of growth decrease with increasing bulk and size, and growth rates vary depending on temperature, salinity, and other factors. However, this and other information indicate that Rangia can reach adult, spawning size somewhere between 1 and 2 years. The emphasis behind the discussion in the preceding paragraphs is to demonstrate that, even though Rangia can conceivably grow to a size > 20 mm in 1 to 2 years, optimal conditions do not occur every year. Due to the dynamic nature of estuarine areas like Lake Pontchartrain, conditions vary considerably from year to year. Salinity and temperature regimes vary depending on precipitation and riverine input, as well as due to man's alterations such as the IHNC and Bonnet Carre' Spillway. Fairbanks (1963) and several other investigators have suggested that predation also plays a role in reduction of numbers of Rangia over the course of a given year. As a result, it probably takes an undetermined number of years for large populations of adult Rangia to become established on a lakewide basis. These large Rangia probably represent the dominant component of the "climax" benthic community in the lakes. The millions of cubic yards of large fossil shells that have been harvested from the lakes attest to the fact that this community existed for thousands of years, although it is likely that natural catastrophes such as hurricanes and major crevasses eliminated large portions of these populations from time to time, followed by a long-term recovery of populations of large clams.

It is likely that clams were always more abundant in the nearshore areas. Tarver and Dugas (1973) found that Rangia populations exhibited a pattern of decreased density as water depth increased and that this pattern was evident even in areas that had not been dredged for 2.5 years. Thorson (1957) stated that free-swimming molluscan larvae are concentrated by wave action in nearshore areas, where they eventually become established. The current patterns in Lake Pontchartrain would likewise tend to concentrate molluscan larvae in nearshore areas, thereby leading to denser populations. Even though nearshore populations

AD-A186 648 CLAM SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS LOUISIANA VOLUME (U) ARMY ENGINEER DISTRICT NEW ORLEANS LA D L CHEW NOV 87 2/5

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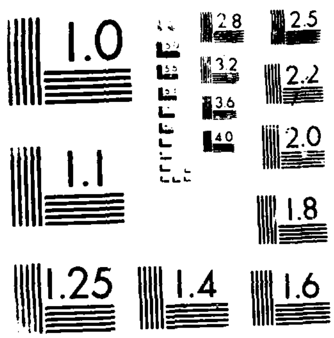

RESOLUTION TEST

occur in greater densities, there were obviously large numbers of clams in offshore areas of the lake as well.

Natural and man-made perturbations have and are affecting the lake and exert impacts on the benthic community. It is difficult, however, to determine the magnitude and significance of these impacts and whether or not the impacts are detrimental to the overall health of the ecosystem. In the case of the large clams, it takes a number of years for their populations to become established in the open lake on a large scale. The calculations of the areal extent of dredging activities indicate that an area equivalent to the permitted area in Lake Pontchartrain is dredged on the average of every four years. In actuality, some areas are disturbed more frequently and some on a less frequent basis; however, it is likely that broad areas of the lake are disturbed with enough frequency to preclude establishment of widespread communities of large *Rangia*. Additionally, areas adjacent to those directly disturbed by passage of the fishmouth are probably affected by a thin layer of fluid mud for a period of time after passage of the dredge. It is estimated on the basis of computer simulations (USCE, 1987) that the fluid mud layer thickness is about 0.5 to 0.8 inch over a distance of 50 feet from the dredge path 1 hour after dredging occurs. Since *Rangia* have relatively short siphons, it is possible that some clams are affected by this layer; however, it is not likely that such a thin layer of fluid mud would cause large-scale impacts to *Rangia* populations.

Shell dredging began in about 1933. Harvest records are available beginning in 1936. During the 17 years of harvest records prior to the time Darnell conducted his benthic surveys in 1953, an annual average of 579,000 cu yd of clam shells was harvested from the lake. During Darnell's surveys in 1953-1954, densities of *Rangia* > 20 mm averaged 136 $\pm$ 16 at 23 open lake stations. Since this period, large clams have never approached this abundance in surveys in the open lake and this has been attributed primarily to shell dredging (Sikora *et al.*, 1981). Childers (1985) reported a dearth of *Rangia* and other invertebrates in the middle of Lake Maurepas where shell dredging had been in operation.

From 1954 to 1972, an average of about 3.9 million cu yd of shell was harvested from the lake annually. This is nearly 7 times the average annual amount of shells harvested prior to Darnell's surveys. Harvest records are not available for 1973 and 1974. However, from 1975-1985, an average of about 5 million cu yd of clam shells was harvested annually. Given this level of dredging intensity, and the fact that it probably takes a number of years for widespread populations of large, live Rangia to become established, it is not difficult to envision why large, live clams are sparse in the open lake. It must be remembered that only a tiny percentage of large clams harvested by the dredgers today are alive. The present day harvest consists primarily of fossil shells. In the area now occupied by Lakes Pontchartrain and Maurepas, these clams have grown and reproduced in abundance for the past 9,000 years (Saucier, 1963). Many generations of clams have existed in the area over thousands of years, thus accounting for the abundant supply of fossil shells harvested by the shell dredging industry. The industry has estimated the life of the industry in the lakes area to range from about 17 to 25 years. If dredging is limited to Lake Pontchartrain, the life of the industry would be 17 years. Industry life would be extended another 8 years if dredging were permitted in Lake Maurepas. Lake Maurepas has about 0.163 cu yd of shell for each m2 of bottom surface area, whereas Lake Pontchartrain has only about 0.074 cu yd of shell for each m2 of bottom surface area.

The above discussion presents a reasonable explanation for the dramatic reduction in numbers of large clams in the lakes; however, other factors must also be considered. It is highly probable that other factors have also affected the clams and other benthic organisms and more than likely function synergistically in causing the documented changes in the benthic community. Appendix D discusses some of these other factors, including lowering of the bulk density of bottom sediments, fluid mud, decreased overall primary productivity, and contaminants.

Regardless of which factor, or combination of factors, has caused the dramatic reduction in abundance of large Rangia, the significance of this reduction to the overall productivity of the lake is the important area of concern. Rangia are consumed by a variety of organisms including fishes, invertebrates, and wildlife. However, most organisms prefer the smaller size classes of Rangia (<5 mm and 5-10 mm), and small Rangia are still relatively abundant, even in many areas of the open lake. In addition to their direct food value for many organisms, Rangia also provide a link between primary and secondary consumers in the lake. In their filter-feeding activities, Rangia ingest large quantities of detritus and phytoplankton. Darnell (1958) reported that gut contents of Rangia contained 70% unidentifiable detritus, 10% sand, and 17% algae, as well as traces of diatoms, foraminifora, and vascular plant material.

Two species of hydrobiid gastropods, Texadina sphinctostoma and Probythinella louisianae have consistently been reported in abundance since the earliest studies in the lake. They have apparently increased in abundance as the large Rangia have decreased. This is not surprising for opportunistic species such as these hydrobiids. They can populate an area very rapidly. Heard (1979) observed P. louisianae in glass culture bowls in the laboratory and noted that the eggs hatched after 8-12 days of development. The small juvenile snails had a fully formed shell and began to crawl about on the sediments and feed. T. sphinctostoma is also known to repopulate very rapidly, and due to its motile veliger stage, is able to travel further distances. Based on this information, it is easy to see how these small snails are able to repopulate dredged areas very rapidly. Hydrobiid gastropods occur in very high numbers in certain estuaries in this country, as well as in Europe and Africa.

These hydrobiids are only about 2-3 mm at maturity and are thought to represent a loss of benthic biomass in the lake (Sikora and Sikora, 1982). The Sikoras estimated that Rangia biomass from Darnell's survey ranged from 20-50 g/m2. Estimates of macrofaunal biomass from their benthic sampling in 1978-79 and 1979-80 were 9.1 g/m2 and 7.9 g/m2,

respectively. These estimates include large and small Rangia, the hydrobiids, and other macrofauna. The significance of this apparent decrease in benthic biomass is not well understood. It is not known if production of fishery resources in Lake Pontchartrain is directly related to benthic biomass. Other factors are involved. For example, large Rangia are consumed by relatively few organisms, so the biomass represented by the larger clams may not be of high value, although it is acknowledged that when the large clams die, their remains ultimately contribute to the overall productivity of the ecosystem.

Numerous other groups of organisms also comprise important components of the benthic community. These organisms include other bivalves (Mulinia, Macoma), copepods, amphipods, mysids, small crabs, chironomids, nematodes, oligochaetes, polychaetes, and others. Many of these organisms are also very opportunistic and can populate areas quite rapidly under proper conditions. Populations of these organisms are often highly seasonal, localized, and sporadic, making quantitative comparisons difficult. However, many of these organisms are very prolific and are probably able to repopulate areas disturbed by shell dredging in a matter of weeks. Those with motile larval stages are able to repopulate distant areas more rapidly. Research has shown also that the decreased stability of dredged sediments adversely affects larval settlement and survival of benthic organisms (Young and Rhoads, 1971; Bloom et al., 1972; Tenore, 1972; and Boesch and Rosenberg, 1981).

The most important aspect of the Taylor (1987) investigation was to compare Sikora's macro-invertebrate data with comparable data to determine the degree of similarity that currently exists between the bottom communities at stations DC and DX (Figure 9). In order to develop a more complete picture of the community status, statistical analyses were conducted by Dr. Stephen A. Bloom (Environmental Data Consultants) to calculate the degree of similarity between DC and DX over time. Dr. Bloom concluded that normally occurring fluctuations in the lake have apparently had more influence on benthic communities at DC and DX than

the experimental dredging done at DX. Using data on macrofaunal abundance, the Sikoras gave the impression of community recovery at station DX sometime between day 250 and day 650. However, Dr. Bloom concluded that if the Sikoras analysis had factored in both species diversity and faunal abundance, it would have shown post-dredging community recovery at DX after about day 250.

Dr. Bloom's 1986 data show some degree of departure from this appearance of recovery characterized by a change in species composition and a marked drop in faunal abundance. However, since routine dredging is prohibited near DC and DX, and over the entire Causeway Conservation and Safety Zone, Dr. Bloom concluded that factors other than shell dredging are probably responsible for any decline in the abundance of infauna that seems to have recently occurred. Although macrobenthos data for DC and DX showed that species composition and animal abundances have changed in the past five or six years, there is no reason to believe that the experimental dredging at DX caused these faunal changes, since both stations have been similarly affected. Dr. Bloom further concluded the benthic community that currently exists in Lake Pontchartrain appears to be an example of a fluctuating, opportunistic assemblage.

In summary, it is well documented that major changes have occurred in the benthic community since the first major studies were conducted in the 1950's. There has been a dramatic reduction in the abundance of large Rangia in the open lake. Information presented in this EIS and appendixes indicate that shell dredging has played a major role in the decline of the large clams. It also appears that shell dredging has caused other changes in the benthic community, including an increase in abundance of the two small gastropods and a variety of other opportunistic benthic organisms. These changes have occurred due to periodic direct disturbance of the bottom sediments. However, there are no data to document that the changes that have occurred in the benthic community have adversely impacted fish and wildlife resources or overall lakewide productivity. Most of the important organisms that prey on

Rangia prefer the smaller clams, which are still plentiful in the lake. Additionally, studies have shown that most of the demersal fish species in the lake are highly opportunistic feeders, preying upon whatever benthic organisms are available.

It should be emphasized that the changes that have occurred in the benthic community began many years ago during the early years of shell dredging. Species abundance and composition undoubtedly experienced major changes due to direct disturbance of the bottom sediments and associated factors. It is likely that the benthic communities that exist in the lake today would change little as a result of shell dredging if dredging continues under existing conditions.

Alternative 2 - No Federal Action (Permit Denial)

Under this alternative, shell dredging activities would totally cease and all impacts related to this activity would be eliminated. The important issue to address under this alternative is whether the bottom sediments and benthic communities would "recover" if shell dredging ceased. Due to the life cycle and environmental requirements of Rangia, it takes a number of years for widespread populations of large Rangia to become established. All other factors being equal, if bottom sediments were not disturbed on a regular basis by shell dredging, benthic communities should begin to recover and approach to some degree those that existed years ago. However, it must be pointed out that other perturbations that have affected the lake could delay or preclude the recovery of benthos to predredging conditions.

3.5.2.2. Fisheries

3.5.2.2.1. Existing Conditions

Lake Pontchartrain functions as a nursery and feeding area for many fresh water, estuarine, estuarine-dependent and marine species. A total

of 129 species of fish representing 55 families have been reported from Lake Pontchartrain (Thompson and Fitzhugh, 1985). The fishery community is dominated by transient species that move into the lake for periods of several months and then emigrate back out to the gulf. The population is dominated by the semi-resident estuarine species component comprised primarily of the bay anchovy (Anchoa mitchilli), gulf menhaden (Brevoortia patronus), and Atlantic croaker (Micropogonius undulatus). These species live in the lake all year, but have certain portions of their population entering or leaving the lake at all times of the year. The freshwater component is also mostly seasonal, with blue catfish (Ictalurus furcatus) becoming more abundant during cooler, less saline periods. In general, the fish population in the lake increases in the spring, reaches maximum numbers in July, and gradually declines through late summer and fall.

Darnell (1958) reported two major food chains in the lake. The first is based upon six major groups of benthic species including polychaete worms, mollusks, chironomids, isopods, amphipods, and xanthid crabs. The second chain consists of planktonic and nektonic food organisms associated with the water column including mysids, copepods, decapods, and fish. Darnell (1961) also reported that organic detritus is a very important food item for many consumers in the lake.

The demersal fishes of the lake have been extensively studied between 1953 and 1978, with more than 850 trawl samples being taken. These studies are discussed briefly here and have been summarized in more detail in Appendix D.

The first substantial fish sampling in Lake Pontchartrain was by Suttkus et al. from 1953-1955. In 1953-1954, a total of 44 species of fish were collected. The bay anchovy and Atlantic croaker were considered to be very abundant, with blue catfish, hogchoker, gulf menhaden, spot, sea catfish, and sand seatrout considered common. During 1954-1955, a total of 60 species were collected. The bay anchovy and Atlantic croaker

were again very abundant, with the gulf menhaden, spot, sea catfish, sand seatrout, and hogchoker (Trinectes maculatus) being common.

Tarver and Savoie (1976) reported on fishes collected from 1972-1974. During 1972-1973, a total of 33 species of fishes were collected. The bay anchovy and Atlantic croaker were the most abundant species, but croaker had declined from the previous surveys in the 1950's. Gulf menhaden, spot, sand seatrout, and blue catfish declined in abundance from the previous studies. In 1973-1974, a total of 27 species were collected. The bay anchovy and Atlantic croaker were again clearly the dominant species.

Thompson and Verret (1980) reported on sampling conducted in 1978. A total of 33 species were collected. As in previous studies, the bay anchovy and Atlantic croaker were very abundant.

Childers (1985) reported on the fishes of Lake Maurepas. A total of 67 species of fish were collected.

Commercial fisheries harvest data described in the following paragraphs are from the National Marine Fisheries Service (NMFS). It should be emphasized that the figures do not include harvest by recreational fishermen, nor do they include all of the harvest by commercial fishermen, as much of the seafood harvested in the lake is unreported. In addition, the lakes also serve as a nursery area for fishery resources that are ultimatly harvested offshore.

Thompson and Stone (1980) discussed the NMFS data for Lakes Maurepas and Pontchartrain from 1963-1975. Crabs, shrimp, and catfish comprised the bulk of the commercial fishery. During this 13-year period, Lakes Pontchartrain and Maurepas accounted for about 9 percent of Louisiana's crab harvest and 0.13 and 0.10 percent of the state's shrimp and fish harvest. The annual blue crab catch ranged from 325,800 to 2,028,300 pounds and averaged about 807 thousand pounds. Shrimp and fishes

accounted for 19 and 14 percent of the value and 10 percent each of the volume of the lake's catch. Commercial finfishing in the lake is dominated overall by catfish and spotted seatrout. Between 1963 and 1975, catfish dominated the catch 11 out of 13 years. Both channel catfish and blue catfish are harvested.

3.5.2.2.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Impacts of shell dredging on fish populations due to suspended sediments may include siltation of spawning areas, affecting developmental and hatching success; reduction in light penetration and associated decrease in productivity; as well as reduction of efficiency of visual feeders; alteration of natural movements, behavior, or migrations; direct effects on gill tissue; and reduced food availability. Several recent reviews summarize the current knowledge of the effects of turbidity and suspended sediments on aquatic organisms (Morton 1977, Peddicord and McFarland 1978; Stern and Stickle, 1978; Guillory, 1982). Based on the results of laboratory studies, investigators often conclude that ecological effects of dredging and associated turbidity are transient and minimal (Stern and Stickle, 1978). Motile organisms have the ability to avoid or vacate areas of excessive turbidities (Guillory, 1982).

Fish, such as bay anchovy, which are visual feeders may be affected by reduced light penetration as a result of increased turbidity; however prey species may be afforded protection from increased concealment (Wilbur, 1971; Stern and Stickle, 1978). In Lake Pontchartrain, bay anchovy appear to feed on whatever small invertebrates are abundant (Levine, 1980).

Fish, shrimp, and crabs may be attracted to a dredging site if suspension of large numbers of invertebrates are associated with the

operation (Viosca, 1958; Stickney, 1973; Guillory, 1982). In Lake Pontchartrain, higher trawl catch rates of gulf menhaden and Atlantic croaker occurred within 200 and 400 ft, respectively, of the dredge than at 1400 ft or baseline (no dredging) stations (Guillory, 1982). Bay anchovy were most abundant at stations 800 ft from the dredge rather than baseline, or closer or farther from the dredge. Although it was not considered a factor by Guillory (1982), avoidance of sampling gear during daylight trawling has been shown to affect catch rates in other systems.

Suspended sediment causes reduced dissolved oxygen levels in the vicinity of the dredge. Decrease in levels of dissolved oxygen may result in behavioral modifications as well as metabolic or physiological changes in fish. Effects of suspended solids on planktonic and nektonic invertebrates are similar to those for fishes including physical abrasion of tissues, clogging of gills, alteration of feeding, swimming, or reproductive success or behavior.

No specific studies on effects of suspended sediments on blue crabs have been conducted. It has been suggested that brown shrimp (*Penaeus aztecus*) may occur in greatest numbers in more turbid areas either due to increased nutritive value of the suspended material or reduced predation (Lassuy, 1983). Turbid water resulting from shell dredging may afford protection to motile invertebrates in an estuary (Sherk, 1971).

Changes in the benthic communities, particularly mollusks, in Lake Pontchartrain have been reviewed in detail in section 3.5.2.1 and Appendix D. The implications of the reduction in densities of larger *R. cuneata* (>20 mm) in the open lake to fishery production is not well understood. Due to their size and thick shells, only a few species prey upon the larger *Rangia*: black drum, sheepshead, blue crab, the oyster drill, and possibly the moon snail (Lasalle and de la Cruz, 1985). In contrast, small *Rangia* are fed upon by a variety of fishes and invertebrates. Most of these other species prefer *Rangia* less than 5 mm (Lasalle and de la Cruz, 1985), and clams of this size are still very abundant in the lake.

Thompson and Fitzhugh (1985) reported on decreases in the relative abundance and frequency of occurrence of several species of fishes that utilize the open-lake benthic habitat and/or are heavily dependent upon the benthic food chain in Lake Pontchartrain. These included the spot, sand seatrout, and a variety of flatfish such as the hogchoker, lined sole, southern flounder, and bay whiff. Levine (1980) examined gut contents and investigated the feeding habits of these and other fishes in the lake.

Spot were found to feed on a great diversity of food organisms. All of the groups of organisms consumed by spot seemed to remain important in all sizes of spot, except for copepods, which were not utilized by larger spot. However, feeding upon smaller organisms seemed to prevail in spot throughout their size ranges. Station by station comparisons from trawl samples seem to indicate that spot are opportunistic, feeding on whatever benthos is most abundant in the area.

Sand seatrout are known to use the open-lake habitats as nursery areas. Based on Levine's findings, small sand seatrout (< 60 mm) depend heavily on copepods and mysids as a food source. However, with growth, larger fishes seem to prefer macrocrustaceans and fishes such as anchovies, ladyfish, silversides, and speckled worm eels. Of these, only the speckled worm eel is associated with the benthic habitat. Mollusks appear to be of little direct use to sand seatrout. Darnell (1958) reported similar feeding habits.

In 69 hogchokers examined by Levine, a variety of benthic invertebrates, primarily chironomids, were found. It is believed that this was due to feeding specialization, as hogchokers are known to feed on a variety of small invertebrates. In 3 hogchokers examined by Darnell (1958), amphipods comprised about 50 percent of the diet. The feeding habits of the southern flounder have been examined by several investigators. It is known to feed primarily on fishes, shrimp, crabs.

Based on the available information, it does not appear that shell dredging has caused a decline in abundance and frequency of occurrence of these four fishes in the lake. The spot and hogchoker appear to directly depend upon benthic organisms, but neither feed on large Rangia. The spot feeds on burrowing organisms during certain life stages. The sand seatrout and southern flounder apparently do not feed on organisms directly associated with the sediments.

The Atlantic croaker, a species that directly utilizes benthic organisms as a food source, has not demonstrated a noticeable decline in abundance or frequency of occurrence. Except for periods influenced by opening of the Bonnet Carre' Spillway, the overall community position of the Atlantic croaker has been relatively unchanged. Croakers are generalized feeders with the young consuming zooplankton, microcrustaceans, and small mollusks. Very small croakers depend heavily upon copepods and amphipods. Adults consume annelids, polychaetes, mollusks, decapods, and small fishes. It is possible that the great diversity in the feeding habits of croakers is the reason they have not exhibited a noticeable decline.

Certain factors other than shell dredging must also be considered and put into perspective when evaluating the fishery trends, including sampling gear used by the investigators, impacts of shrimping, the potential decrease in overall primary productivity, contaminants, loss of wetlands surrounding the lakes, and the high degree of inaccuracy in recorded commercial fishery landings. These factors are discussed in Appendix D and Section 3.8 (Cumulative Impacts) of this EIS.

One way to assess the health of the fish populations in Lake Pontchartrain is to compare the area with other estuaries in the Mississippi Deltaic Plain. A total of 129 species representing 55 fish families are known from the lake. The species/family ratio is 2.3. The only estuaries with more species reported are Barataria Bay (186) and the Terrebonne/Timbalier estuary (147). Species/family ratios in the Deltaic

Plain range from a low of 2.0 for Four League Bay to a high of 3.0 for Barataria Bay. Based on this data, Lake Pontchartrain compares favorably with other areas. Thompson and Fitzhugh (1985) calculated species diversity (proportional make up of the fish community), species richness (the relative number of species), and evenness (how even the numbers of individuals are distributed among the total assemblage). Species richness demonstrated a decline from the 1950's to the 1970's, declining from 4.5 to 2.6.

It is difficult to quantify the impacts of shell dredging to fishery production. However, it is possible to discuss impacts to fisheries in a qualitative manner. Shell dredging has played a role in alteration of the benthic communities. The question that remains to be answered is whether or not the changes have caused significant adverse impacts to Lake Pontchartrain fisheries. However, as demonstrated by the discussions in the Cumulative Impacts Section (Section 3.8) and throughout this EIS, many other factors also affect the health of Lake Pontchartrain, and the individual and synergistic impacts of these various factors tend to mask the impacts of any particular factor. Thompson and Fitzhugh (1985) stated that a logical explanation for the apparent decline of sand seatrout, spot, hogchoker, bay whiff, southern flounder, and lined sole from the 1950's to the 1970's is the deteriorating benthic conditions in the deeper, open-lake areas of Lake Pontchartrain. However, these authors, as well as many other investigators, have also acknowledged many of the other factors affecting the lake and have, likewise, been unable to quantify the impacts of individual activities affecting the lake.

In summary, studies indicate there has been a decrease in the abundance and frequency of occurrence of some demersal fish species since the 1950's, including sand seatrout, spot, hogchoker, and southern flounder. These species are known to utilize the open-lake habitats and several investigators have indicated that the decline of these species may be due to stresses in the open-lake environment. Based on studies of

the feeding habits of these and other demersal fish species, there is no evidence that shell dredging has adversely affected these fish due to impacts on the food chain. The spot and hogchoker appear to depend directly upon benthic organisms as a food source, but neither feed on large Rangia. The sand seatrout and southern flounder do not feed primarily on benthic organisms directly associated with the sediments and rarely consume mollusks. Atlantic croaker, the second most abundant fish species, directly utilize benthic organisms as a food source, but apparently have not declined in abundance. As mentioned previously, most of the demersal fish species are highly opportunistic feeders, consuming whatever benthic organisms are available. As discussed previously in this section and in Appendix D, turbidity can affect aquatic organisms in numerous ways. The temporary, localized turbidity associated with shell dredging activities affects a very small percentage of Lake Pontchartrain at any given time, and fishery impacts related to short-term turbidity in Lake Pontchartrain are not considered significant. In Lake Maurepas, where it has been shown that shell dredging causes lakewide, persistent elevated levels of turbidity, impacts to fishery resources as a result of turbidity could be significant. With regard to the impacts of long-term turbidity on fish production, long-term turbidity increases, to which shell dredging may contribute, may adversely impact the productivity of grassbeds, phytoplankton, and benthos. Since these resources are of value to fisheries, it is acknowledged that these impacts may adversely impact fishery populations to some extent. Overall, data indicate that the fishery community in the lakes is relatively healthy when compared to other Louisiana estuaries.

Alternative 2 - No Federal Action (Permit Denial)

Under this alternative, shell dredging activities would totally cease. There would be no periodic distu bance of the bottom sediments and benthic organisms, no shell dredging-induced turbidity, and no

potential for release of contaminants by the shell dredgers. Any impacts to fishery resources which may occur as a result of shell dredging would be totally eliminated.

3.5.2.3. Wildlife

3.5.2.3.1. Existing Conditions

A variety of wildlife species inhabit the area. Although the wetlands surrounding Lakes Maurepas and Pontchartrain support most of the wildlife, the lakes themselves are of direct value to some species.

Migratory puddle ducks common to the area include mallard, green-winged teal, blue-winged teal, pintail, American wigeon, gadwall, and northern shoveler. These ducks primarily inhabit the marshes adjacent to the lakes, but also utilize the shallow, nearshore areas of the lakes for resting and feeding. Mottled ducks are resident to the area and also use the marshes and nearshore areas. Wood ducks nest in the wooded swamps and seasonally-flooded bottomland hardwoods surrounding the lakes. The American coot is very common in the area, utilizing both the marshes and nearshore-lake areas. Snow geese are also known to occur in the marshes surrounding the lakes.

Diving ducks known to winter in the area include ringnecked duck, lesser scaup, greater scaup, hooded merganser, redbreasted merganser, bufflehead, redhead, ruddy duck, common golden eye, and canvasback. These diving ducks, particularly scaup, often utilize the lakes proper.An estimated 500,000 lesser scaup winter in Lakes Maurepas and Pontchartrain (Tarver and Dugas, 19/3).

Game birds other than waterfowl that inhabit the marshes adjacent to the lakes area include rails, gallinules, and common snipe. A variety of non-game birds are found in the area including wading birds, seabirds, shorebirds, songbirds, and raptors. Common wading birds which use both

the marshes and nearshore areas of the lakes include great and little blue herons, Louisiana heron, green heron, night herons, great egret, snowy egret, reddish egret, and white and white-faced ibises. Seabirds include primarily a variety of gulls and terns. Shorebirds include black-necked stilt, killdeer, willet, greater and lesser yellowlegs, and a variety of sandpipers. Marsh hawk, belted kingfisher, and a wide variety of songbirds are common in the marshes near the lakes.

Amphibians are generally found in the fresher marshes and nearshore lake areas and primarily include frogs and toads. Reptiles found in the marshes and nearshore lake areas include the American alligator, common snapping turtle, alligator snapping turtle, softshell turtles, diamondback terrapin, red-eared turtle, stinkpot, and several species of water snakes, including the western cottonmouth.

Several species of furbearers, including nutria, muskrat, river otter, mink, and raccoon are found in the marshes adjacent to the lake and also utilize the nearshore-lake areas. These animals are harvested commercially for their pelts.

3.5.2.3.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Shell dredging activities as currently permitted have minimal impacts on wildlife resources in the lakes. Nearly all of the species in the area are found in the wetlands adjacent to the lakes or utilize the shallow, nearshore waters around the periphery of the lakes. Since there is a one-mile restricted zone around the periphery of the lakes, it is highly unlikely that wildlife utilizing the marshes and nearshore lake areas would be impacted by shell dredging activities.

Diving ducks, particularly lesser scaup, are very abundant in the open waters of Lake Pontchartrain. As previously mentioned, as many as

500,000 lesser scaup overwinter in the Lake Pontchartrain area every year. Lesser scaup in Lake Pontchartrain prey heavily on Rangia and other small mollusks (Suttkus et al., 1954; Darnell, 1958; Gunter and Shell, 1958; and Tarver and Dugas, 1973). Scaup prey primarily on juvenile clams smaller than 5 mm (Harmon, 1962 and North Carolina Bureau of Sport Fisheries and Wildlife, 1965). Although the abundance of large Rangia in Lake Pontchartrain has apparently experienced a dramatic decline, small Rangia and other clams still occur in great abundance. It is unlikely that shell dredging is a limiting factor to the abundance of lesser scaup and other diving ducks in Lake Pontchartrain.

Alternative 2 - No Federal Action (Permit Denial)

Since it is unlikely that shell dredging significantly affects wildlife resources, impacts of this alternative would be very similar to Alternative 1.

3.5.2.4. Endangered and Threatened Species

3.5.2.4.1. Existing Conditions

Coordination has been initiated and maintained with both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) regarding the occurrence of endangered and threatened species in the Lakes Maurepas and Pontchartrain area and the potential impacts of shell dredging to any of these species. In a letter dated June 30, 1986, USFWS indicated that no endangered or threatened species under their jurisdiction would be impacted by the proposed activity and no further consultation would be required.

In a letter dated July 8, 1986, NMFS provided us with a list of endangered and threatened species under their jurisdiction that may be present and potentially impacted by shell dredging. The list consisted of the Kemp's (Atlantic) ridley sea turtle, Lepidochelys kempi, which is

endangered, and the loggerhead sea turtle, _Caretta caretta_, which is threatened. NMFS advised the New Orleans District that a biological assessment should be prepared to identify potential impacts to these species as a result of shell dredging. A biological assessment has been forwarded to NMFS and is included as Appendix A to this EIS. The results of the assessment are summarized in the following paragraphs.

Several individuals have reported sighting sea turtles in the Lake Maurepas and Lake Pontchartrain area. It is believed that the turtles were ridleys. No loggerheads have been reported. No sea turtles have been captured by the shell dredgers (Don Palmore, Pers. Comm.). During most periods of the year, any turtles which may be in the vicinity of a dredge would be expected to avoid capture. From December through February, water temperatures could be low enough to cause the turtles to become sluggish, and perhaps even hibernate, making them susceptible to capture by the dredge. However, there is no information to indicate that the turtles do hibernate in the lakes, nor is it likely that large numbers of turtles utilize the lakes. The assessment concluded that the impacts of shell dredging on sea turtles is negligible.

3.5.2.4.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Renewal of permits which would allow the shell dredging to continue under existing conditions would have negligible impacts on endangered and threatened species.

Alternative 2 - No Federal Action (Permit Denial)

Cessation of shell dredging in the lakes would eliminate any possibility of impacts, however slight, to endangered and threatened species which may occur in the area.

3.6. ECONOMIC ENVIRONMENT

3.6.1. **Business and Industry**

3.6.1.1. Existing Conditions

Shell dredging operations in the Pontchartrain Basin have represented a relatively small but important component of the industrial corridor which extends, essentially, from the Port of Baton Rouge to the Port of New Orleans and the mouth of the Mississippi River. Following World War II, this area experienced rapid economic expansion led by dramatic increases in oil and gas production, waterborne commerce, marine construction, petroleum processing, space technology, highway construction, and in tourism and related construction. Economic activity in the area has ranged from about 40 to 60 percent of the state's total sales, receipts, value added by manufacture, and employment. The large volume of clam shells found in Lakes Maurepas and Pontchartrain has been an important source of aggregate and calcium carbonate for use in this development. The most detailed information available regarding Louisiana's shell industry has been reported by the Louisiana Wildlife and Fisheries Commission and the agency which has since replaced it - the Louisiana Department of Wildlife and Fisheries (LDWF). These agencies, along with the Department of Natural Resources (DNR), have had significant authority and responsibility in the state's regulation of the industry. To document its procedures, the Louisiana WildLife and Fisheries Commission published a report in December of 1968 outlining The History and Regulation of the Shell Dredging Industry in Louisiana. As discussed in that report, the state's regulation of clam shells began in the early 1930's when significant quantities were first harvested through the use of sweeper dredges. Fluctuating periodically, demand increased from about 200,000 cu yd to more than 5,000,000 cu yd by the mid-1960's (see Figure 2). The following table lists the major uses of both clam and oyster shell in Louisiana in 1968. At that time, the volumes of clam

shells harvested from the lakes and oyster shells harvested from the central gulf coast were about the same.

Uses of Clam and Oyster Shell on a Percentage Basis

General Construction	32.6%
Road Construction	31.4%
Cement	17.4%
Petroleum and Chemical Production	11.0%
Lime	6.8%
Agricultural Uses (Chicken Feed)	0.4%
Glass	0.4%

Source: Louisiana WildLife and Fisheries Commission, 1968.

A more recent analysis furnished by the Louisiana Shell Producers Association estimates that from 1980 to 1985 about 80 percent of all shell harvested in Louisiana was used for general construction and maintenance (roadway base course, parking lots, roads, petroleum drill pads, and levees); 10 percent for acid neutralization, smoke stack emission control, chemicals, and pharmaceuticals; about 5 percent for lime production; and another 5 percent for oyster reef cultch (Douglass, 1986). Three aggregate supply companies are currently dredging clam shells in the lakes area, including Pontchartrain Materials, Louisiana Materials, and Dravo Basic Materials (formerly Radcliff Materials). Two of these companies also handle other aggregate materials such as limestone, sand, and gravel.

The state's 1968 report suggested that there might be continued reproduction of clams sufficient to maintain a reserve supply; however, it also pointed out that the gradual decrease observed in the size of clams taken could reflect their gradual depletion. A subsequent study, also done by the Louisiana Wildlife and Fisheries Commission, supported the latter assessment that an annual harvest of 5,000,000 cu yd of clam

shells from the lakes could represent a depletion rate at least 90 times that of the annual rate of deposit (Tarver and Dugas, 1973).

Total shell production in Louisiana continued to increase until the 1970's. Table 6 compares the combined production and value of both clam and oyster shells harvested in Louisiana during the 1960's wit.. trends in other Gulf Coast states. The same source estimated a conversion factor of 1 cu yd = 0.875 short tons of shell. Values shown reflect a general pattern of decline. The market value of shell during the 1960's was influenced by a wide range of factors including such things as transportation costs, construction trends, oil and gas production, resource availability, changes in material specifications, environmental concerns, governmental regulation, and an apparent shake-out in the industry encouraging greater diversification of individual companies (Arndt, 1976). Table 7 shows more recent trends in the volumes of clam shell harvested from the lakes area and oyster shells from the central coast, and the amount of royalties generated by each. Production in Louisiana over the past decade exhibits a pattern of decline similar to that experienced by other shell producing states in the gulf, although not entirely for the same reasons. The decline of Lake Pontchartrain clam shell production results from a combination of factors related to regional and industry economic conditions, and environmental regulatory policies of the state.

The major economic factors influencing demand and production are the maturation and recent decline of the regional petroleum industry, the secondary effects of this decline on the state economy and growth, and completion of major road building projects. The rapid expansion of oil production and oil field construction which occurred during the 1950's and 1960's peaked in 1972. During this same period both I-10 and I-55 were built. The subsequent reduction of demand for basic construction materials has been reflected in shell output and output of other aggregates. The total production of shell of 1985 was about 44% of the

TABLE 6

Recorded Shell Production and Value in the Gulf Coast Region, by States, 1960-69

(Production in short tons)

	Louisiana		Texas		Fla., Ala., Miss.[1]		Total	
Year	Production	Value	Production	Value	Production	Value	Production	Value
1960	4,691,114	$ 8,881,608	10,304,451	$15,798,494	2,758,658	$6,088,093	17,754,223	$30,768,195
1961	4,641,276	7,655,928	10,531,247	15,372,759	1,564,459	4,651,429	16,736,982	27,680,116
1962	5,711,481	8,066,647	10,072,803	14,701,243	3,188,868	5,936,924	18,973,152	28,704,814
1963	5,408,182	7,961,135	9,300,794	13,306,513	2,782,641	5,037,298	17,491,617	26,304,946
1964	5,459,044	7,227,803	9,989,946	15,077,078	3,283,067	5,084,940	18,732,057	27,389,821
1965	7,452,421	10,905,244	9,689,357	15,355,914	3,231,047	4,946,184	20,372,825	31,207,342
1966	8,091,318	11,252,763	9,364,618	12,839,355	3,090,339	5,016,135	20,546,275	29,108,253
1967	7,599,395	11,174,114	10,776,368	15,417,035	2,854,353	4,639,158	21,230,116	31,230,307
1968	9,387,333	11,748,503	7,851,155	10,784,751	3,095,000	4,268,601	20,333,488	26,801,855
1969	9,237,470	11,891,976	7,177,148	8,577,868	2,839,156	5,836,771	19,253,774	26,286,615

1 Combined to avoid revealing individual company confidential information.

Source: R. H. Arndt, 1976.

TABLE 7

Louisiana Clam and Oyster Shell Production and Royalties by Year

Year	CLAM Production (Cu/yds)	CLAM Royalties Dollars	OYSTER Production (Cu/yds)	OYSTER Royalties Dollars	TOTALS CLAM & OYSTER Production (Cu/yds)	TOTALS CLAM & OYSTER Royalties Dollars
1975	7,374,059	1,511,232	4,806,506	742,390	12,180,565	2,253,622
1976	6,648,132	1,362,235	4,615,746	782,314	11,263,879	2,144,550
1977	6,078,527	1,245,892	4,548,424	749,729	10,626,952	1,995,622
1978	6,041,969	1,238,603	4,124,892	683,237	10,166,862	1,921,840
1979	5,546,530	1,168,981	3,994,149	657,569	9,540,680	1,826,550
1980	5,066,040	1,089,198	3,560,458	583,537	8,626,498	1,672,735
1981	4,857,931	1,044,455	3,391,911	571,248	8,249,843	1,615,703
1982	3,897,249	1,031,543	2,446,141	613,615	6,343,390	1,645,159
1983	3,331,056	1,049,282	3,287,296	859,548	6,618,352	1,908,831
1984	3,302,710	1,079,976	3,198,864	868,740	6,501,575	1,948,716
1985	2,923,076	990,922	3,163,058	897,623	6,086,134	1,888,546

Source: State of Louisiana, Department of Wildlife and Fisheries. Unpublished data. June, 1986

maximum reported level which occurred in 1974, while 1985 sand and gravel production amounted to 67% of the 1976 peak value.

State regulations aimed at accommodating environmental concerns over shell operations in the lake have also had a depressive effect on output. Restrictions in total pumping capacity and exclusion of operators from highly productive near-shore zones have combined to lower output directly as well as to raise costs in the face of declining demand.

Competition from imported aggregates such as limestone does not appear to be a significant factor locally as it has been in other gulf states due to the lack of nearby deposits, high transportation costs, and the unique attributes demonstrated by clam shell in coastal construction applications.

More recent studies also indicate a relatively sharp increase in the price of shell, reflecting not only its importance to the local economy, but also increases in transportation costs and the rising price of fuel. A 1986 analysis by Dr. William Barnett II, prepared for the Louisiana Shell Producers Association in conjunction with this study, estimates the price of shell at $11.30/cu yd. The annual harvest of 3,000,000 cu yd of shell, sold at that price, would be valued at $33,900,000. At the present time, Louisiana is the only state in the Gulf area harvesting shells for industrial purposes (Barnett, 1986a). Dr. Barnett's study indicates that increases in restrictions by regulating authorities have resulted in substantial reductions in the volume of shell harvested causing the per unit operating cost to increase (Barnett, 1986a). These costs have by necessity been passed on to users in the form of higher prices.

Activities of this basic materials industry tend to have a multiplier effect, influencing indirectly other businesses and industries. Includ-ing total sales, resales, production and transportation costs, royalties

and severance taxes, and state and local sales taxes, and estimating a multiplier factor of three, overall economic effects of an annual production of 3,000,000 cu yd of clam shell could be on the order of $142,000,000 (Barnett, 1986a). Dr. Kenneth J. Boudreaux, another area economist, has estimated that the value of direct and indirect economic transactions generated by the shell dredging industry may be in the neighborhood of $226 million, assuming a multiplier factor of five (Boudreaux, 1984).

A preliminary report by the U.S. Bureau of Mines (1987) indicates that the 1986 production of sand and gravel in Louisiana was approximately 16,970,000 short tons, while "stone" (primarily shell) was estimated at 5,400,000 tons. Using a conversion factor of 0.875 ton equals one cubic yard of shell the 1986 estimate for shell production in Louisiana would be about 6.2 million cubic yards, about the same as in 1985. This estimate includes both clam shell from the lakes area and oyster shell from the gulf cost area. A March 1987 quote for limestone delivered to New Orleans was $12.50 per ton. The density of limestone is significantly greater than the density o. shell. Using a conversion factor of 1.75 to 1.00, the price of a cubic yard of limestone delivered to New Orleans is estimated to be about $22.00. Other aggregates commonly used are sand, gravel, and clay. A more detailed discussion of alternati e materials is presented in Section 2.2.1.1.

In addition to clams, other economically important resources harvested from the lakes include a variety of finfish and shellfish. Recreational and sport fishing, shrimping, and crabbing generate a market for boats, motors, fishing equipment, and various related supplies and services. In addition, the seafood harvested from the lakes by commercial fishermen and crabbers support local seafood markets and indirectly stimulate the New Orleans tourist trade. Thompson and Stone (1980) concluded that blue crab is the dominant commercial fishery of Lake Pontchartrain. They found that during the period of 1963 to 1975, blue

crab accounted for, on the average, 67 percent of the value and 79 percent of the volume of the lake's harvest. Annual harvest varies between 45 and 96 percent of total catch.

Shrimp and fishes accounted for, on the average, 19 and 14 percent, respectively, of the value and 10 percent each of the volume of the lakes catch. Annual shrimp harvest varies from zero to 41 percent of total catch.

In 1975, the exvessel value of the total commercial fishery catch in Lakes Pontchartrain and Maurepas was estimated to be approximately $242,700, of which $222,900 was blue crab. In the same year, the value of total commercial blue crab landings in Louisiana, as reported by the National Marine Fisheries Service (NMFS), was estimated at $2,665,000. The value of all reported commercial fishery landings in Louisiana was $89 million. The figures indicated above are at price levels unadjusted for the effects of inflation.

Roberts and Thompson (1982) report that the harvest of blue crab from Lake Pontchartrain and Lake Borgne (an adjoining water body) has generally declined, while demand and prices have increased. Tables 8 and 9 compare the volume and value of hard and soft blue crab landings in Lakes Pontchartrain and Borgne. In a later report (Aquanotes, 1983), Roberts points out that the blue crab fishery in the Pontchartrain area represents a large cottage industry - difficult to measure due to the large number of crabbers who are part-time operators. He suggests that the true commercial harvest from Lakes Pontchartrain and Borgne might be as much as six times the reported catch. It should be pointed out that the landings for other commercial species are probably also underreported, and the harvest of seafood, particularly shrimp, by recreational fishermen is not reported at all. In 1985, hard blue crab landings in Louisiana reported by NMFS totaled 29,848,488 pounds valued at $8,586,400. Soft crab landings totaled 82,102 pounds valued at

TABLE 8

Hard blue crab landings and value from Lake Pontchartrain and Lake Borgne, 1959-1985.

year	pounds	value	1985 value	% of state lbs.*
1959	2,848,000	136,704	504,916	30
1960	2,661,300	133,065	483,758	26
1961	2,961,800	127,357	458,485	25
1962	2,551,300	125,014	445,212	27
1963	2,069,480	115,891	407,866	26
1964	1,598,400	107,093	371,720	28
1965	1,887,200	128,330	437,977	20
1966	1,624,000	108,808	361,177	20
1967	1,933,700	133,425	430,402	26
1968	2,144,500	180,138	557,851	23
1969	2,377,100	218,693	642,673	21
1970	2,119,200	192,847	534,996	21
1971	1,615,100	210,007	558,220	13
1972	1,799,000	230,531	544,170	12
1973	2,687,000	378,370	916,639	12
1974	1,402,900	234,386	511,876	7
1975	1,189,800	211,055	422,110	7
1976	1,294,000	283,814	537,402	9
1977	1,586,900	445,604	792,016	10
1978	1,418,700	346,450	572,196	10
1979	2,049,332	474,921	704,735	10
1980	2,800,127	698,454	912,530	15
1981	1,521,269	481,115	569,592	9
1982	1,249,805	429,952	479,869	7
1983	2,488,683	874,892	945,408	15
1984	2,727,578	874,352	905,391	--
1985	2,878,695	926,282	---	--

* Percentage of Louisiana's hard blue crab catch from the lake system.

Sources: 1959-1978, Roberts and Thompson (1982).
1979-1985, Unpublished. Furnished by the NMFS.
1985 values computed using the Consumer Price Index (CPI) from 1987 Statistical Abstract of the United States.

TABLE 9

Soft blue crab landings and value from Lake Pontchartrain and Lake Borgne, 1959-1985.

year	pounds	value	1985 value	% of state lbs.*
1959	209,300	104,650	386,525	35
1960	255,200	127,600	463,890	50
1961	278,100	139,050	500,580	45
1962	117,100	58,550	208,514	34
1963	126,420	63,210	222,461	39
1964	58,600	37,504	130,176	29
1965	57,000	39,300	134,127	28
1966	45,300	29,898	99,243	35
1967	54,500	45,235	145,919	37
1968	94,500	68,985	213,632	33
1969	75,800	62,156	182,658	39
1970	25,700	22,873	63,454	29
1971	55,600	52,068	138,402	44
1972	42,600	46,070	118,740	42
1973	57,800	65,934	159,732	48
1974	34,600	48,440	105,788	36
1975	30,600	42,940	85,880	28
1976	26,500	42,881	85,880	30
1977	64,000	169,092	300,544	28
1978	1,200	3,150	5,202	1
1979	63,940	154,802	229,710	44
1980	54,540	129,689	71,256	46
1981	62,025	149,381	176,852	62
1982	52,825	143,277	159,911	--
1983	51,423	157,449	170,679	--
1984	7,341	22,927	23,740	--
1985	6,303	18,539	---	--

* Percentage of Louisiana's soft blue crab catch from the lake system.

Sources: 1959-1978, Roberts and Thompson (1982).
1979-1985, Unpublished. Furnished by NMFS.
1985 values computed using the Consumer Price Index (CPI) from <u>1987 Statistical Abstract of the United States</u>.

[Revised]

$199,600. The value of all commercial fish and shellfish landed in the state in 1985 was $229,134,000, again at unadjusted price levels.

In comparison, reported 1985 commercial landings in the Lake Borgne-Pontchartrain area totaled about 8,032,000 pounds with an exvessel value of $7,392,000. Of the total value, about $6,222,000 was from shrimp landings, while approximately $946,000 was from crab landings. Another $179,000 was from oyster landings. If the area's blue crab catch was as much as six times the volume reported by NMFS, the gross value of the 1985 catch would be $5,676,000. Data collected by NOD for a 1984 Louisiana Coastal Area study indicated that inshore landings of shrimp may be under reported by as much as 200 percent. It was estimated that oysters might be under reported by as much as 150 percent. The estimated value of the commercial catch (rather than "landings") from the lakes area south and eastward to Southeast Pass and Garden Island Bay was $48,785,000. This figure indicates the continued productivity of the lakes and adjacent areas. As in the case of shell production, commercial fishing and the economic activities associated with recreational fishing also have a multiplier effect, creating employment and income not only for those directly involved in the harvest of seafood but those working in related sales, services, and tourism.

Based on an estimated value of $11.30/cu yd, the gross value of clam shells harvested from Lake Pontchartrain in 1985 was $33 million, a figure significantly greater than the gross value (to the fisherman) of to the total commercial fish and shellfish catch from Lakes Pontchartrain and Borgne as reported by NMFS, even considering that the fisheries are probably underreported. Production from both the shell and fishing industries, however, represents only a small fraction of the value of total sales, receipts, and manufacturing productivity generated in large metropolitan areas like New Orleans and Baton Rouge.

3.6.1.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

The impacts of permit issuance would include continued operation of the three companies currently dredging shells in the lakes with the current limitations imposed by the various state and federal regulatory authorities. As discussed by Juneau (1984) and others, the LDWF and DNR have developed a monitoring system for measuring and controlling potential environmental impacts which may be felt damaging to the resources under their regulatory authority. In recent years, for example, dredging in Lake Maurepas has been prohibited, reducing the reserves available for shell dredging in the Maurepas/Pontchartrain area by 30 percent (Barnett, 1986b). The following table indicates the state's estimates of remaining clam shell resources as of February 1973.

Estimated Remaining Resources
(cubic yards)

	High	Low
La. Estimate of February 1973*	178,413,200	91,446,400
Less: Approx. production since date of estimate**	69,000,000	69,000,000
Remaining Resources	109,443,200	22,446,400

*Louisiana WildLife and Fisheries Commission, 1973.
**William Barnett, II, 1986.

With increasing restrictions and continued production, differences between the 1973 estimates of high and low remaining reserves have become more significant. Barnett's current estimate of remaining clam shells in the area total 75.45 million cu yd, including 52.7 million cu yd in Lake Pontchartrain and 22.75 million cu yd in Lake Maurepas. While there appears to be no way of measuring the volume of remaining shell with precision, this estimate falls within the range of remaining resources

estimated by the state. Assuming that most of the remaining shell in the lakes could be economically harvested, and that the average rate of harvest would be 3 million cubic yards annually, the remaining life of the industry would be approximately 25 years. If Lake Maurepas remained closed, the estimated remaining life of the industry would be about 17 years (Barnett, 1986a). Considering the prospects of increasing operating costs with the depletion of reserves, it seems probable that economic forces would tend to discourage continued production of one or more of the permitted companies before total depletion of clam shells in the lakes. As the harvest of shell declines, the demand for alternate sources of aggregate would tend to increase, and this source of raw material would gradually decline as it has in other states.

Alternative 2 - No Federal Action (Permit Denial)

The general impacts to business and industry resulting from permit denial could include a small, but unquantifiable net increase in the productivity of commercial fishery resources in the lakes area; however, they would also include the premature halt of the area's 50-year-old shell dredging industry, including the loss of employment, income, and capital investments. It has been estimated that shutting down shell dredging operations would result in a $29,250,000 loss of capital investment, assuming that equipment currently in use could be salvaged at $750,000 (Barnett, 1986a). The Louisiana Shell Producers Association's latest annual report compares the price of shell in New Orleans at $10.00 per cu yd and the price of stone at $18.00 per cubic yard. The Barnett study referred to previously and coordinated with industry representatives estimated the price at $11.30 per cubic yard. Fluctuations in the price of shell and alternative materials are linked to transportation costs as well as the availability of the resources. If and/or when the regulated harvest of shell is discontinued, the cost of materials for which shell is an acceptable substitute would increase due to market forces, increasing cost pressure on local manufacturers.

3.6.2. **Desirable Regional Growth**

3.6.2.1. Existing Conditions

As indicated in the previous section, shells harvested from the lakes area have been an important source of aggregate and raw material for many years and have contributed to the overall regional economic development, just as the availability of abundant fish and wildlife resources was a major contributor in the area's early development. While the lake area remains an important source of raw material, seafood, and recreation, as well as cultural identity for those living in the region, other factors have tended to contribute more to the area's overall growth, including such things as improvements in technology, population increases, the abundance of natural gas and crude petroleum, and proximity to two of the world's more active deep-water ports.

3.6.2.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Renewal of the shell dredging permits under the current regulating system and restrictions would have only an incremental impact on regional growth. As discussed previously, shell dredging and commercial fishing in Lake Pontchartrain represent only a small portion of the area's overall economic activity. As the availability of shell in the lake area declines, the cost of production, the price of shell, and the demand for alternative materials, will tend to increase. A gradual restructuring of aggregate and calcium-carbonate activities based on market forces, as would occur under this alternative, rather than further governmental regulation could reduce related adverse impacts and disruption to the industry and related impacts to regional growth. To the degree that the continued harvest of clam shells adversely impacts fishery resources and overall environmental quality, regional growth could also be adversely impacted, although to a significantly lesser degree.

Alternative 2 - No Federal Action (Permit Denial)

If the permit is denied, shell dredging operations in the lake would be shut down sooner than anticipated. There would be an immediate loss of employment and income generated by the industry would stop. While economic development in the region would no doubt continue, the restructuring of its basic materials industries, including greater dependence on resources not immediately available, would have a somewhat negative impact on regional growth. As indicated in Table 11, shell accounted for about 20 percent by volume of aggregate materials produced in the state during the 1985-1986 reporting period. Economic activities anticipating the availability of shell in their production forecasts would be required to seek alternative sources of raw materials. For some users, this may not be feasible. Unless an economical alternative can be found, the loss of clam shells for use as oyster cultch would represent an additional notable adverse effect of permit denial.

3.6.3. **Employment/Labor Force**

3.6.3.1. Existing Conditions

Table 10 compares recent employment trends in the economic area and the state. Data from the Louisiana Department of Labor reflect the significant rise in unemployment since the latest detailed estimates reported by the Bureau of the Census. While all of the parishes in the economic study area are not immediately adjacent to the lake, resources harvested from the lake tend to impact regional employment and income trends, both directly and indirectly. The civilian labor force in the study area represented 45 percent of the state total in August of 1986. Of the 800,000 employed, most worked in service, marketing, and transportation-related industries. Other major sources of employment were manufacturing and mineral production.

TABLE 10

CIVILIAN LABOR FORCE

(in 1,000's)	Revised August 1986				Revised August 1985				Revised August 1984				1980 Census			
	Labor Force	Empl.	Un-empl.	Rate	Labor Force	Empl.	Un-empl.	Rate	Labor Force	Empl.	Un-empl.	Rate	Labor Force	Empl.	Un-empl.	Rate
Louisiana	1,968.3	1,725.2	243.1	12.3	2,004.8	1,768.9	235.9	11.8	1,955.9	1,768.1	187.8	9.6	1,788.1	[illegible]	104.7	6.0
Lakes Area																
New Orleans LMA**	586.2	524.9	61.3	10.5	614.7	544.9	69.8	11.4	583.8	529.9	53.9	9.2	[illegible]	[illegible]	41.5	6.7
Baton Rouge LMA***	259.4	233.3	26.1	10.1	259.1	230.4	28.7	11.1	[illegible]	231.4	21.5	8.5	221.8	[illegible]	12.4	[illegible]
Tangipahoa Parish	39.2	33.8	5.4	13.6	37.8	31.8	6.0	15.9	36.4	[illegible]	[illegible]	[illegible]	30.5	[illegible]	[illegible]	8.3
Plaquemines Parish	10.5	9.4	1.1	10.5	15.1	14.0	1.1	7.3	4.8	13.8	1.0	6.7	9.7	[illegible]	[illegible]	[illegible]
	895.3	801.4	93.9	10.5	926.7	821.1	105.6	11.4	887.9	806.3	81.6	9.2	[illegible]	[illegible]	47.0	5.8

* Totals may not equal sums due to rounding procedures.

** New Orleans Labor Market Area: Jefferson, Orleans, St. Bernard, St. Charles, St. John, and St. Tammany Parishes. While shell is used in all coastal parishes it is not currently harvested from all coastal waters, including those immediately adjacent to St. Bernard Parish or Plaquemines Parish.

***Baton Rouge Labor Market Area: Ascension, East Baton Rouge, Livingston, and West Baton Rouge Parishes. Livingston is the only parish within the Baton Rouge, LMA immediately adjacent to the Lakes Area.

Sources: State of Louisiana, Dept. of Labor, "Louisiana Labor Market Information," 1984, 1985, 1986.
U.S. Dept. of Commerce, Bureau of the Census, 1980 Census of Population," Characteristics of the Population, General Social and Economic Characteristics, Louisiana.", 1981.

In the first quarter of 1986, about 61,000 people in the study area who were covered under the Louisiana Employment Security Act were working in manufacturing jobs and another 23,000 were employed in mineral production. Barnett's report (1986a) indicates that the three companies currently permitted by the state to dredge shells in Lake Pontchartrain employ 302 people, generating an anticipated 768,904 manhours in 1986. Using a multiplier factor of three, Barnett estimates that an additional 906 jobs and 1,902,600 manhours of employment will be generated indirectly as a result of shell dredging activities. Boudreaux (1984) has suggested that a multiplier factor of five might be appropriate in estimating the indirect employment generated by this basic industry. Using the more conservative multiplier factor, the total number of jobs created by the shell dredging industry is 1,208. A recent report by the Louisiana Shell Producers Association estimated employment in both the lake and gulf coast areas total 500 jobs, indirectly contributing to 9,000 jobs with an annual payroll of $50 million.

Estimating the level of employment generated by both recreational and commercial fishing, shrimping, and crabbing is more speculative. Blue crab is by far the most important species commercially harvested from Lake Pontchartrain. Roberts and Thompson (1982) indicate that about 185 commercial crab licenses were sold to residents living adjacent to the lakes in 1980; however, the interview sample done in conjunction with the study indicated that about 38 percent of those licensed were part-time, rather than full-time, crabbers. On the other hand, other studies indicate that the lake's catch of blue crabs may actually be six times greater than the catch reported in NMFS statistics. Employment generated by recreational and sport fishing, crabbing, and shrimping is more difficult to measure. It includes sales and services of boats, motors, and fishing and hunting equipment from a wide range of retail and wholesale outlets which also market a variety of other products unrelated to recreational fishing and hunting.

3.6.3.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions.

If the Corps permits are issued under the current regulations and restrictions, the 302 jobs of people directly involved in shell dredging and an estimated 906 jobs indirectly involved could be sustained until depletion of the resource made production no longer economical. As the remaining volume of shell declined, related employment would tend to decline. As previously discussed, time is a significant factor. While the industry is more than 50 years old, the demand for shell has been declining for a number of years, and the remaining life of the industry under current regulations and production levels is estimated at less than 20 years. Recent decline in other important minerals, specifically oil and gas production, has made shell dredging more important as a source of local employment. Barnett (1986a) estimates that the 302 shell dredging employees, and 906 employees indirectly supporting the industry, generate about $26,715,000 of income annually. As shell dredging declines, however, this level of income will decline as well. To the degree that shell dredging impacts commercial fishery resources, related employment would be adversely impacted. As shell dredging declines, fishery related adverse impacts could also decline, improving the employment potential generated by commercial and sport fishing and hunting.

Alternative 2 - No Federal Action (Permit Denial)

The following table shows the estimated employment impacts of permit denial assuming that the existing companies could remain in operation, as middlemen, continuing to supply the area's demand for alternative material.

Employment Retained/Created if
Alternative Materials are Used

	Jobs	Manhours
Pontchartrain Materials	10	22,500
Louisiana Materials	10	22,500
Dravo Basic Materials	10	22,500
Support Companies (service, supply, etc.)	453	951,300
	483	1,018,800

Source: William Barnett II, 1986a.

Barnett's analysis assumes that indirect impacts to local employment would be a reduction of about 50 percent. Based on this assumption, the direct and indirect impacts to local employment resulting from a complete shut-down of shell dredging operations at this time would be the loss of 725 jobs. The estimated loss in wages and fringe benefits would be $16,527,000 in the first year alone. The higher cost of alternative materials would be factored into the overall cost of production and construction, including labor costs. On a broader scale, adverse impacts to employment would be the net number of jobs which would be lost in the manufacture of durable goods. To some extent, adverse impacts to the national economy would be offset by employment in the production of alternative materials in other places. While limestone and other products represent alternatives to clam shells, their higher costs of production and/or transportation could add to the marginal cost of construction and manufacturing, influencing decisions regarding employment as well as capital investments. In view of these considerations, it seems probable that permit denial could have an indirect adverse impact on employment in the production of related durable goods. To the degree that permit denial could reduce environmental damage caused by shell dredging and improve productivity of commercially important fishery resources, the potential for related employment would increase sooner than otherwise anticipated. Unless limestone or some other material ultimately proved to be an acceptable substitute for use as oyster

cultch, there could also be related adverse impacts to employment in the oyster industry.

3.6.4. **Property Values**

3.6.4.1. Existing Conditions

Decisions regarding the regulation of shell dredging influence property values in two areas: first, the value of capital investments made by the industry itself, and more indirectly, investment decisions which depend on the availability of shell or other forms of aggregate and calcium carbonate. As discussed in the section on business and industry, the capital investments made to establish shell dredging operations in Lake Pontchartrain are currently valued at $30 million; more indirectly, the availability of shell as an important building material has helped to keep down the cost of construction and the manufacture of cement, lime, chemicals, and other manufactured products. Other property values impacted by shell dredging operations could be capital investments of the local commercial fishermen. Using data compiled by Roberts and Thompson (1982), the average market value of commercial crab boats was estimated at $10,500. The total value of 185 boats at $10,500 would be about $1.9 million.

3.6.4.2. Impacts of Alternatives

<u>Alternative 1</u> - Renew Permits With Existing Conditions

Among the beneficial impacts of permitting continued shell dredging in the lake would be sustaining the economic viability of the operator's specialized equipment as long as economically recoverable shell exists. As the availability of shell declines, however, the value of the equipment would tend to decline.

Alternative 2 - No Federal Action (Permit Denial)

Assuming the three companies currently dredging shells from the lake could all adjust to become suppliers of alternative materials, a primary adverse impact of permit denial on property value would be the decline in value of the companies' capital equipment. As previously mentioned, the estimated current value of shell dredging equipment is $30 million; however, its salvage value is estimated at only $750,000, reflecting a loss of $29,250,000. This assumes that clam shell dredging would also be denied at other locations in the state. At the present time, Louisiana is the only state along the Gulf Coast where shells are still being dredged. Barnett (1986a) has reported that California and Maryland are the only other states where shell dredging is a commercial enterprise. If commercial activities supporting shell operations decline by 50 percent, the value of related properties could also decline, at least temporarily. The loss of employment resulting from permit denial and the potential for population displacements would tend to adversely affect the local housing market that is already depressed due to a decline in oil and gas industries.

3.6.5. **Public Facilities and Services/Transportation**

3.6.5.1. Existing Conditions

Public facilities and services influencing, or influenced by, shell dredging are primarily roads, streets, channels, bridges, docking facilities, and related activities of municipal, state, and Federal regulating authorities.

Over 80 percent of total shell usage during the 1980-1985 period was for general construction and maintenance (roadway base course, parking lots, roads, drill pads, and levees) (Douglass, 1986). Assuming an annual production of 3 million cu yd of shell production in the study area, approximately 2.4 million cu yd was used for these purposes. The

majority of this usage was for public construction and maintenance of roadways. Shell cost and functional characteristics outperform competing materials for these tasks.

In south Louisiana there is a shortage of aggregates for use in highway and airport construction. The nearest limestone quarries are located in Alabama, but most of the limestone now used in Louisiana comes from Missouri and Kentucky where it can be shipped by less expensive water transportation (Douglass, 1986). Sand and gravel, also produced in Louisiana (see Table 11), are alternatives for use in road construction, although shell may be the recommended material.

The Louisiana Department of Transportation and Development (DOTD) uses shell as a base course material, in asphaltic concrete, as a shoulder material, and as an embankment in marsh and swamp areas. Shell products, such as lime and portland cement, are also used. DOTD's evaluation indicates that shell has engineering properties that make it an extremely useful building material. Because of its shape, it provides high particle interlock, which results in high shear strength (resistance to movement). This quality makes shell a superior material for bridging over soft foundations, such as marsh or swamp.

DOTD geologists say that shell aggregates produce a base course equal to that of crushed stone in load-carrying capacity. Since crushed stone has to be imported in large quantities for use in base course construction, use of shell results in considerable savings to the public. When stabilized with cement, shell produces a base course that is superior to any aggregate available in Louisiana. In parts of the state where shell is available, use of a cement-stabilized shell base course results in reduced thickness due to additional strength developed.

The DOTD, in cooperation with Louisiana State University, conducted research on building "Floating Embankments" through marsh and swamp for the relocation of U.S. 90 west of Raceland, using shell as the embankment

material. Based on this research, they concluded that it would require only half as much shell, compared to sand, to construct an embankment in this marsh area. In addition, the required right-of-way for a shell embankment is approximately 50 percent less than for a sand embankment. The reason for less right-of-way for shell, compared to sand, and for less quantity of shell, is the fact that the shell embankment requires no berms for stability, as does the sand. This smaller right-of-way required also lessens the environmental impacts of the project. On one project alone, this resulted in a savings to the taxpayers of some $17,000,000 (DOTD, 1986).

3.6.5.2. Impacts of Alternatives

ALTERNATIVE 1 - Renew Permits with Existing Conditions

Continued production would provide aggregate used in construction and maintenance of roads, levees, parking lots, and other projects. Public services would continue to be enhanced through collection of royalties and severance taxes.

ALTERNATIVE 2 - No Action (Permit Denial)

This would cause an immediate impact on highway and airport construction in southern Louisiana (DOTD, 1986). Other aggregates, with higher transportation costs, would have to be imported from other states. Some of the engineering properties that make shell a useful building material, such as high particle interlock, are not found in other aggregates. In a marsh and swamp area, such as parts of southern Louisiana, twice as much sand is required to construct an embankment than when shell is used. In addition, the required right-of-way for a shell embankment is approximately 50 percent less than for a sand embankment. Both of these factors amount to added expenses to the taxpayers if shells are not available.

Public services would also suffer from the loss of royalties and severance taxes collected by state government. Increased outlays for unemployment payments and other social services for those employees losing their jobs would further add to government budgetary problems and reduce the availability of services overall. Unemployment benefits in Louisiana, at the present time, can be as much as $205.00 per week for up to 26 weeks, for a total of $5,330.00.

3.6.6. Tax Revenues

3.6.6.1. Existing Conditions

In addition to the royalties collected in conjunction with regulation of the shell industry, the state collects severance taxes of $.06/ton. Table 11 compares severance taxes collected by the State of Louisiana in the 1985-86 fiscal year. The figure for shells includes both oyster shells harvested from the coast and clam shells harvested from the lakes. As indicated previously, royalties generated from clam shell production in 1985 totaled about $1.0 million, in addition to the severance taxes indicated in the table.

In addition, employment and income created by the industry generates federal and state income taxes and state and local sales taxes. As of September 1986, Louisiana was receiving royalty rates of $0.352 per cubic yard. Although no other Gulf states are currently producing shell, the latest royalty rates were $1.40 per cubic yard in Texas, $0.22 per cubic yard in Florida, and $0.30 per cubic yard in Alabama (Douglass, 1986). Likewise, commercial and recreational fishing and hunting generate income and sales taxes.

TABLE 11

Distribution of General Severance Tax (1985-1986)
(Source: Louisiana Department of Revenue, Severance Tax Section)

Resources	Tax Basis	*Product Quantity	Rate	Tax[3]
Oil/Condensate	Value	186,743,286.43	12 1/2 Value[1]	533,761,390.59
Gas	MCF	1,740,016,533.00	.07 MCF[2]	119,819,142.98
Gasoline & L.P.G.	Barrels	71,788.00	.05 to .10 Bbl.	13,170.85
Sulphur	Long Tons	2,218,829.00	1.03/Long Ton	2,285,393.88
Timber	Tons	10,706,327.07	**	4,563,767.93
Gravel	Tons	8,351,454.68	.06/Ton	502,052.09
Pulpwood	Tons	11,960,814.40	**	2,981,174.44
Shell	Tons	4,638,582.74	.06/Ton	284,428.50
Sand	Tons	9,279,027.61	.06/Ton	537,322.43
Salt	Tons	5,760,637.68	.06/Ton	353,137.88
Salt Brine	Tons	9,544,564.40	.005/Ton	47,784.47
Stone	Tons	268,934.74	.03/Ton	8,067.75
Lignite	Tons	.00	.10/Ton	.00
Iron Ore	Tons	.00	.10/Ton	.00
Reforestation				
Timber	Tons	49,248.37	**	57,724.51
Pulpwood	Tons	125,677.24	**	47,907.04

*Volume figures are unaudited.

**Rates are set annually by the Louisiana Tax Commission and Louisiana Forestry Commission. For this period, the rates range from as little as .07 per ton in the case of hardwood pulpwood to as much as .53 per ton on other timber.

[1]Approximate percentage of value per barrel.

[2]Approximate percentage of value per MCF.

[3]Tax figures include interest and penalties charged to industries filing late.

3.6.6.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Taxes generated by shell dredging operations would continue as long as the resource could be economically harvested. Tax revenues would be required to monitor and control adverse impacts.

Alternative 2 - No Federal Action (Permit Denial)

If the permit is denied, royalties, severance taxes, and income and sales taxes generated by the harvest of shell in the lake would no longer be collected. To the degree that alternative sources of aggregate and calcium carbonate could economically replace the demand for shell, taxes generated in production of the alternative material would contribute to the tax base at the production site where the product is generated.

3.7. SOCIAL ENVIRONMENT

3.7.1. **Esthetic Values**

3.7.1.1. Existing Conditions

Esthetics of the economic area include the massive waterway of the Mississippi River emptying into the Gulf of Mexico, urban landscapes of Baton Rouge and New Orleans, the broad expanse of Lakes Maurepas and Pontchartrain, and a rare blending of forests, marshes, natural levees, and winding bayous.

3.7.1.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Since shell dredging activities are restricted near the shoreline, esthetic impacts in Lake Pontchartrain are limited to the vicinity of the dredge and are not considered significant. Impacts to esthetic values in Lake Maurepas could be significant due to lakewide elevated levels of turbidity caused by shell dredging.

Alternative 2 - No Federal Action (Permit Denial)

Any impacts to esthetic values as a result of shell dredging would be eliminated.

3.7.2. **Archeology/Cultural Resources**

3.7.2.1. Existing Conditions

The waters of Lake Pontchartrain have been traversed by watercraft since prehistoric times. Several well-preserved sailing skiffs and pirogues have been found along the north shore of Pontchartrain and within the sediments of Maurepas. There is no doubt that many other locations contain nautical resources. Stout (1985a, 1985b) located a 120-foot sailing ship deemed potentially eligible for the national Register. The shipwreck is located near-shore well within the area restricted to shell dredging.

The decade of the first recorded shipwreck occurrence in Lake Pontchartrain is 1810-1819 and the decade of most frequent recorded wreck occurrences is 1860-1869. With the exception of the Mississippi and Atchafalaya Rivers, the Lake Pontchartrain area has the highest number of recorded wrecks within the New Orleans District. However, such wrecks were not reported from Lake Pontchartrain until after 1910. Lake

Pontchartrain was traveled by steamboats, schooners, barges, keelboats, sloops, and barge-schooners or schooner-barges. Unrigged barges were not listed until the 20th century. With one exception, all barges from the lake area enrolled between 1804 and 1860 carried two or three masts.

Saltus (1985) recorded 71 commercial vessels operating in Lake Maurepas between 1808 and 1860. These included schooners, barges, steamboats, sloops, and one keelboat.

During the post civil war period, commercial activity continued to increase. By the early twentieth century, commercial activity had begun to decline.

At present, there are approximately 80 recorded shipwrecks in Lake Pontchartrain. Exact locations are unknown. Within the lake, water velocity, sedimentation, subsidence, and erosion are all conducive to the preservation of shipwrecks. Due to the amount of ship traffic and commerce in the Lake Pontchartrain area, shipwreck potential greatly exceeds the recorded number of wrecks. However, extensive shell dredging has occurred in the lake since 1933, and there are no reports of shipwrecks being encountered.

Inundated terrestrial cultural resources exist in Lake Pontchartrain and there have been two known cases of shell dredges impacting these types of sites, one in the 1930's and one in the 1960's. The sites are located in an area of the lake that is open to dredging.

Alternative 1 - Renew Permits With Existing Conditions

There are no known cultural resources eligible for listing or listed on the national Register of Historic Places located in the permit area. Any Department of the Army Permits, if issued or extended, would contain special and general conditions requiring the permittee to notify the Corps if any previously unknown historic or archeological remains are

discovered while performing the activity authorized by the permit. The Corps would then initiate the Federal and state coordination required by 33 CFR Part 325, Processing of Department of the Army Permits; Procedures for the Protection of Cultural Resources. Additionally, the New Orleans District is currently developing an Underwater Cultural Resources Management Plan that incorporates the waterbodies of the project area. Data generated during the development of the plan will be used as a reference tool.

Alternative 2 - No Federal Action (Permit Denial)

If the permits are denied, there would be no potential for disturbance of archeological or cultural remains by shell dredges.

3.7.3. **Desirable Community Growth**

3.7.3.1. Existing Conditions

Desirable community growth is linked to a variety of interdependent factors including such things as the availability of a stable source of employment and income; adequate utilities; the maintenance of streets and sanitation; police, fire, and flood protection; health care; and the quality of education.

3.7.3.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Permitting the continued harvest of shell in the lakes as currently authorized would result in the continued employment and income generated by the industry and thereby accommodate community development as long as the remaining resources could be economically harvested. To the degree that continued shell dredging adversely impacts commercially important fishery resources of the lake, associated employment and income would be

adversely affected, inhibiting growth potential of fishing communities in the area. Based on the difference between the gross values of shell and commercial fisheries at current market prices, the potential impacts of the former appear to outweigh the growth prospects of the latter. However, the availability of shell is limited, while there is potential for the harvest of fish and shellfish beyond depletion of the clam shell resource. The continued availability of shell for construction and other uses, at competitive prices, would help to sustain growth in local areas.

Alternative 2 - No Federal Action (Permit Denial)

If shell dredging is no longer permitted, one of the immediate effects would be the loss of employment that would probably force some local residents to seek jobs elsewhere. The higher cost of alternative materials could discourage growth, particularly in communities experiencing the adverse effects of a decline in the oil industry.

3.7.4. **Community Cohesion**

3.7.4.1. Existing Conditions

The social harmony of communities in the economic study area has depended on a wide range of factors including not only the physical environment, employment and income opportunities, and the availability of public facilities and social services, but the cultural history which many community residents have in common. To maintain overall community cohesion and resolve conflicts not addressed by other institutions, local, state, and federal governments have developed the current system of regulation. It is the legal means by which communities can respond to changes in social, economic, and/or environmental conditions. As discussed previously, the current regulating process involves review by a variety of state and federal agencies. It has included both public hearings and opportunities for written comment by all individuals and groups interested in the use and quality of the lakes. There has been

substantial public debate over the impacts and importance of shell dredging. The Corps of Engineers, in its regulating procedures, coordinates with the LDWF which

> "... has the authority to alter, suspend, or terminate all or part of its lease agreement if it considers an area to be environmentally sensitive...and in danger of being significantly damaged...... Zones, restricted areas, and seasons are utilized in an effort to provide more comprehensive management for all interests..." (Juneau, 1984)

In 1984, the LDWF granted a request by DNR, Division of Water Pollution Control, to suspend shell dredging operations in Lake Maurepas until their effect on turbidity levels could be evaluated. The state Attorney General's Office has requested further documentation regarding decisions previously made concerning the issuance of shell dredging permits.

3.7.4.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Since experts disagree over the level of impact which shell dredging and other factors may have on the productivity and environmental quality of the lakes, continued shell dredging under the current system of regulation would probably result in continued controversy between user groups. Completion of this EIS should satisfy some questions pertaining to the advisability of shell dredging in the lakes; however, over the years various uses of the lakes and the subject of shell dredging have become emotionally charged issues, as well as ones in which reasonable people sharply disagree, thus continued dredging would carry with it the continuation of some level of conflict within the community.

Alternative 2 - No Federal Action (Permit Denial)

Permit denial would have adverse impacts on the social harmony of the region insofar as it would result in the ultimate loss of employment and income of an estimated 725 wage earners and the issues which that action would entail (Barnett, 1986a). The effects would be particularly severe at this time due to the recent decline of the oil industry that has already caused substantial adverse impacts. The historical conflict between shell dredging interests, fishermen, and environmental groups would be eliminated. However, focus of concern over uses of the lakes would shift to other activities which also may impact the fishery productivity and water quality of the lakes.

3.7.5. **Noise**

3.7.5.1. Existing Conditions

Major factors influencing noise in the economic study area are industrial activities along the waterways and vehicular traffic along major highways and thoroughfares. Dredges and equipment used in harvesting shell, separating it from other dredged material, and emptying it onto barges, also create significant noise levels. The distance between shell dredging operations and the shore of the lakes limit noise impacts. No dredging may be conducted within three miles of the shoreline in Orleans Parish and within one mile of the shoreline in the other parishes around the lakes.

Adverse impacts associated with noise levels would essentially be limited to the 15 to 20 employees working on each dredge. Studies of the noise impacts on a comparable dredge operating in Mobile Bay indicate that noise levels recorded in the engine room were in the 100 decibels range and in the upper deck the noise level was about 80 decibels. Noise levels 2,000 feet away from the dredge were measured at 60 decibels. Noise levels of 80 decibels or higher over sustained periods of time are

considered injurious to health and could impair hearing. Dredge operations are subject to the requirements of the Federal Occupational Safety and Health Administration.

3.7.5.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Noise associated with continued shell dredging operations would be limited to those dredges being used under existing conditions as long as shell could be economically harvested.

Alternative 2 - No Federal Action (Permit Denial)

If shell dredging is no longer permitted, the noise generated by transporting alternate materials would tend to increase, but would probably have no significant adverse impact on local communities or the region.

3.7.6. **Recreation**

3.7.6.1. Existing Conditions

An abundance of recreational opportunities exist in the lakes area. Structural and nonstructural recreational features exist along with rural and urban settings. Wildlife and fishing-oriented activities also occur. Hunting activities include waterfowl, rabbit, squirrel, and deer hunting. Fishing activities include crabbing, shrimping, and finfishing. Shrimping is generally heaviest in dry years when salinities in Lake Pontchartrain are slightly elevated.

The Jefferson and Orleans Parish lakefront is facility-oriented. Primary facilities along the shore of Jefferson Parish include boat launches, fishing piers, and a linear park. In Orleans Parish,

facilities include picnic shelters, playgrounds, covered pavilions, fishing piers, marinas, and boat launches, along with ancillary facilities and shoreline recreation. Other activities such as fishing, crabbing, walking, and biking are prevalent activities on the south shore. No hunting is allowed on the lakefront areas of Orleans and Jefferson Parishes.

On the western shore of Lake Pontchartrain, hunting and fishing activities dominate. Existing are the Joyce and Manchac Wildlife Management Areas, encompassing 13,569 and 8,323 acres, respectively. These areas are hunted for waterfowl, rabbit, squirrel, and deer. On the northern shore of the lake are Fairview and Fountainbleau State Parks. These areas provide access to the shore of the lake for fishing and crabbing activities. Day use and overnight facilities are available at both parks. Private and commercial marinas also exist along the northern shore and provide boating access and harbor for both sailing and motorized vessels.

Resident and non-resident recreational fishing and shrimping licenses issued for the 1984-1985 season in Orleans, Jefferson, St. Charles, St. John the Baptist, Tangipahoa, and St. Tammany Parishes totaled 85,393 resident and non-resident for fishing and 2,201 resident and non-resident for shrimping. These licenses provide an indication of the potential number of recreational fishermen that use the lakes area. Most of the fishing that occurs in the area is by boat. Boat use is reflected by the 50,463 recreational boat registrations issued by the LDWF for the parishes around the lakes during 1984-1985. In addition to recreational fishing activities, boats are also used for pleasure boating, sightseeing, and skiing. Although these registered boats also use other waters of the adjacent parishes, they provide an order of magnitude figure for the number of recreational vessels using the lakes.

3.7.6.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Due to the buffer zones that exist around the shoreline of the Lake Pontchartrain, it is unlikely that shell dredging would exert any significant impacts on recreational activities occurring along the shorelines. The only potential for recreational impacts would be in the open-lake areas and these would be limited to the areas in the vicinity of operating dredges. The zoning restrictions imposed upon the shell dredgers in Lake Pontchartrain allow the dredges to operate in only two zones at any given time. The schedule for operation in these zones is determined annually by the LDWF, and emphasis is placed on reducing conflicts among user groups. Due to the vast expanses of Lake Pontchartrain, there are always plenty of areas in which to recreate without competition from shell dredgers. The primary impact would be a transfer of use from the area affected by dredging to an undisturbed area of the lake. It is acknowledged, however, that a dredge or dredges may be operating in a highly desirable fishing location, thereby forcing a fisherman to fish in a location of lower preference. On the other hand, there are those who seek out dredges and fish in their vicinity, claiming that the stirring up of the bottom releases food items which attract small fish and invertebrates which, in turn, attract larger fishes such as croaker, seatrout, and drum. In Lake Maurepas, where shell dredging has been shown to cause very high lakewide levels of turbidity, recreational fishing could be significantly impacted.

Alternative 2 - No Federal Action (Permit Denial)

Under the no action alternative, shell dredging activities would totally cease, thereby eliminating any possibility for conflicts between shell dredgers and recreationists.

3.7.7. **Displacement of People**

3.7.7.1. Existing Conditions

Table 12 compares recent population trends in the economic study area. As the table indicates, population from Baton Rouge to the mouth of the Mississippi River has almost doubled in recent years. From 1950 to 1985, total population of the economic area increased by almost 95 percent while population nationwide increased less than 60 percent. Economic activity and transportation improvements which stimulated and accommodated this growth included significant increases in the demand for shell, particularly in the 1950's and 1960's. As discussed previously, demand for shell increased from 2.4 million cu yd in 1950 to a peak of 7.4 million cu yd in 1975. Recently, however, economic fluctuations, significantly influenced by the decline of petroleum prices and production, have caused high unemployment and outmigration in the New Orleans area.

3.7.7.2. Impacts of Alternatives

Alternative 1 - Renew Permits With Existing Conditions

Allowing continued shell dredging operations under the current regulating system would help to sustain local employment and income, and to limit related population displacements which might otherwise occur. As the volume of shell remaining in the lakes is depleted, related employment in the shell industry would gradually decline; however, a gradual decline in response to market forces would probably reduce the prospect of family dislocations.

Alternative 2 - No Federal Action (Permit Denial)

Permit denial would result in the immediate loss of jobs in the local area and contribute to the current pattern of unemployment and outmigration. Assuming the three companies currently harvesting shell from the

TABLE 12

Population Trends in the Maurepas-Pontchartrain Region

	1950	1960	1970	1980	1985
Baton Rouge MSA*	**	**	**	**	***
Ascension Parish	22,387	27,927	37,086	50,068	57,817
East Baton Rouge Parishes	158,236	230,058	285,167	366,191	390,915
Livingston Parish	20,054	26,974	36,511	58,806	71,249
West Baton Rouge Parish	11,738	14,796	16,864	19,086	20,697
Sub-total	212,415	299,755	375,628	494,151	540,678
New Orleans MSA*					
Jefferson Parish	103,873	208,769	338,229	454,592	476,022
Orleans, Parish	570,445	627,525	593,471	557,927	564,383
St. Bernard Parish	11,087	32,186	51,185	64,097	68,046
St. Charles Parish	13,363	21,219	29,550	37,259	42,384
St. John the Baptist Parish	14,861	18,439	23,813	31,924	40,556
St. Tammany Parish	26,988	38,643	63,585	110,869	137,635
Sub-total	740,617	946,781	1,099,833	1,256,668	1,329,026
Plaquemines Parish	14,239	22,545	25,225	26,049	26,680
Tangipahoa Parish	53,218	59,434	65,875	80,698	90,325
Total Study Area	1,020,489	1,328,515	1,566,561	1,857,566	1,986,709
% of state	38.0	40.8	43.0	44.2	44.3
Louisiana	2,683,516	3,257,022	3,644,637	4,206,312	4,480,681

* MSA - Metropolitan Statistical Area

** U.S. Department of Commerce, Bureau of the Census, Census of Population, Louisiana 1960, 1980.

*** Louisiana State Planning Office, Spring 1986 State Planning Bulletin.

lakes downsized to become middlemen supplying alternative materials, the estimated loss of employment would still be 725 jobs (Barnett, 1986a), which would cause population displacements. To the degree that the decline of shell dredging operations increased production of alternative materials in other areas, the potential for population displacement in these areas would decline. At the present time, however, unemployment rates in the New Orleans and Baton Rouge metropolitan areas are above the national average.

3.7.8. **Public Safety**

3.7.8.1. Existing Conditions

About half of the area open to shell dredging in Lake Pontchartrain lies west of the Lake Pontchartrain Causeway, which is an elevated concrete bridge supported on pilings (Figure 1). Dredges, shell barges, fuel barges, and other floating equipment pass under this span in transit from western dredging sites to bases located on the Inner Harbor Navigation Canal. Additionally, oil and gas exploration activities and ship repair and building facilities located west of the causeway generate large-vessel traffic requiring bridge transit. Since the causeway was opened to vehicular traffic in 1956, the bridge has been struck and badly damaged six times by floating equipment which veered from the two main navigation channels under the bridge. In each of these cases, one or more of the pre-cast bridge deck sections collapsed into the lake. In 1964, six people were killed as a result of one of these incidents when a passenger bus fell into the lake before traffic could be halted. Three other persons lost their lives in 1974 in a similar accident. Both of these fatal accidents involved shell dredging vessels or equipment. At least two of the six incidents resulting in bridge closure were caused by non-shell related equipment. In addition, several other minor accidents have occurred which resulted in damage to only the bridge pilings.

Repairs for a major accident normally take from 1 to 2 weeks and are payable by the party found to be liable. The last time a roadway section was lost, in 1984, repair costs amounted to about $600,000. Prior to 1969, when a parallel two-lane roadway was added on an independent piling foundation, an accident of this nature resulted in considerable inconvenience and cost to commuters and businesses which depend on the bridge. Travel time by the alternate routes across the lake are about an hour longer. Since the second span has been added, no accident affecting both spans has occurred and regularly spaced crossovers have been used to establish two-way traffic on the undamaged span until repairs can be completed. This results in generally minor congestion.

In 1985, a Collision Avoidance Warning System (CAWS) was installed on the causeway. Commercial towboats and dredges that transit the lake are required to carry electronic gear that sounds an onboard alarm within one mile of the causeway and which is also monitored by the Louisiana Department of Wildlife and Fisheries (LDWF) station at the New Basin Canal. Cost of the system was about $300,000, which was evenly divided among the Causeway Commission, the LDWF, and the shell dredging industry. Since this system has been in operation no serious accidents have occurred. Recent newspaper articles, however, have reported concerns of the causeway General Manager and others that the system is being compromised because equipment required to be aboard commercial vessels is poorly maintained or missing, enforcement is lax, fines for violations are inadequate, and budgetary decisions have reduced the number of enforcement personnel.

Another bridge which in the past has experienced serious damage directly related to dredging operations in the lake area is the U.S. Highway 51 bridge near the community of Manchac. This bridge, along with the nearby I-55 and the Illinois-Central Railroad bridges, provides transportation over Pass Manchac, a channel which connects western Lake Pontchartrain to Lake Maurepas (Figure 1). In 1976 the highway bridge was struck by a barge tow delivering shell from a dredge in Lake

Pontchartrain to a retail site located on the western shore of Lake Maurepas. Due to swift currents in the pass and other factors, this vessel was unable to navigate the two poorly aligned openings through the highway and railroad bridges. In the resulting collision, a section of the roadway was toppled into the channel. The life of one motorist was lost in this accident, and injuries were sustained by two other individuals. Reports of the loss of another vehicle were never confirmed. Repairs to the bridge required six months to complete. Although a foot passenger ferry was established during this period, vehicular traffic was required to re-route at considerable expense and inconvenience because the I-55 bridge was not yet complete at that time. The railway bridge was not badly damaged in this accident and remained in use.

In 1983, the state closed Lake Maurepas to shell dredging; however, movements through the lake such as described above still occur. While no collision warning device such as CAWS is known to protect these bridges, a continuous fendering system has been added since the accident which presumably would have prevented this collision and any similar accidents. None of the other large vessels which infrequently transit these bridges are known to have caused any serious damage.

3.7.8.2. Impacts of Alternatives

<u>Alternative 1</u> - Renew Permits With Existing Conditions

A continuation of dredging operations under the current system of permits would carry with it some risk of the span being struck as has happened in the past. Such accidents have a demonstrated lethal potential. This risk can clearly be reduced to an extremely low order of probability, however, if the CAWS is administered and operated in a manner that fully exploits the potential of the system.

It is not considered likely that the state will reopen Lake Maurepas to shell dredging. If such were the case, however, the risk of collisions unlike those responded to by the bridge modifications cited above, as well as possible fatalities, would escalate unless some additional preventive measures are taken.

To the extent that the availability of large supplies of relatively cheap shell and the tax and royalty revenues derived from the production of shell contribute to a higher level of road building and maintenance, permit renewal would probably comprise an unquantified positive impact on the safety of the motoring public.

Alternative 2 - No Federal Action (Permit Denial)

Permit denial would cause all dredging operations in the lake to cease. The risk of the causeway being struck by these vessels would likewise end. Some small risk of collision from the relatively fewer other large commercial vessels operating in the lake would remain, however. The dimensions of this risk would depend in part on the future decisions affecting operation of the CAWS.

Although accident of the character described above involving the bridges at Manchac would likely be prevented by the improved fendering system, other sorts of collisions outside the normal navigation channel could conceivably occur. Permit denial would preclude any such potential increase in risk of collision which would result if the state ban on dredging in Lake Maurepas were to be lifted. The existing degree of risk related to other commercial vessels presently operating in the lake area would remain.

3.8. CUMULATIVE IMPACTS

This EIS assesses the impacts of shell dredging on the Lakes Maurepas and Pontchartrain ecosystem. Throughout the document, references are made to other activities that occur in the study area and cause some of

the same types of impacts as shell dredging. The purpose of this section is to discuss some of these activities in more detail so reviewers will be aware that numerous other activities affect the lakes area and that many of the impacts generated by these activities are similar, and often inseparable, from those caused by shell dredging. The cumulative impacts affecting Lakes Pontchartrain and Maurepas are those discussed below as well as the impacts caused by shell dredging that have been discussed previously in this EIS.

3.8.1. **Sewage Introduced Into the Lakes**

The lakes area receives sanitary waste discharges from many of the municipalities, subdivisions, industries, public institutions, and private facilities located in the Lake Pontchartrain Basin. The quantities of discharge range from a few gallons per day to several million gallons per day. The level of treatment afforded these discharges ranges from none to conventional secondary biological waste stabilization. Thus, the biochemical oxygen demand (BOD5) of the wastewaters can range from over 200 mg/L to less than 30 mg/L. Furthermore, fecal bacteria densities can vary from millions of bacteria colonies per 100 mL of discharge to less than 200/100 mL. Consequently, where the sanitary waste discharges are significant, low dissolved oxygen concentrations, high BOD concentrations, and high fecal bacteria densities are typically cited problems. Often, concomitant water quality problems involve inordinately high nitrogen, phosphorus, and suspended solids concentrations. Trace metals and complex synthetic organics may also be components of these municipal type wastewaters. However, these pollutants are not normally a problem unless a significant portion of the total discharge is industrial process water instead of sanitary waste. Consequently, for most municipal wastewaters, the concentrations and mass loadings of the conventional pollutants - BOD, fecal bacteria, pH, suspended solids, nitrogen, and phosphorus are of primary concern. In terms of human health concerns, the fecal bacteria, as indicators of the potential presence of pathogens associated with human waste, are probably the most important pollutant.

The BOD concentration and pH of the discharge are the probably most important concerns related to the health and maintenance of aquatic life.

Both the quantity and quality are important considerations in assessing the impact of sanitary waste discharges on receiving waters. High pollutant concentration - small discharge rate, and low concentration - large discharge rate couplings can have equivalent impact in terms of the mass loading of pollutants to receiving waters. For each regulated discharger, a National Pollution Discharge Elimination System (NPDES) permit delineates restrictions on flow rate and the concentrations and mass loadings of specific pollutants or aggregate pollution measures. Typically, for a municipal wastewater discharge, the maximum daily and 30-day moving average flow rates are restricted. The 7-day and 30-day moving average fecal bacteria densities, BOD and suspended solids concentrations, and 30-day moving average BOD mass loading are restricted also.

Unfortunately, discharge restrictions are often violated. Where treatment facility capacity is adequate for the population served and groundwater and stormwater infiltration and inflow (I&I) to the sewage collection system is not excessive, normally, only minor permit violations occur. Typically, minor permit violations are due to transient, and infrequent, treatment process upsets. However, when treatment facilities are overloaded and I&I is significant, gross and frequent permit violations become the norm. Typically, these gross violations result from discharging raw or partially treated sewage, intentionally bypassing all or a portion of the treatment facility. The 1982 bacterial pollution study of Lake Pontchartrain by the Louisiana Department of Health and Human Resources indicates that sewage bypassing has been a significant problem in the study area. Data appended to the study report indicate that during 1980 a metro New Orleans wastewater discharger reported (in compliance with provisions of its NPDES permit) 171 sanitary wastewater bypass events. Of the 171 bypass events reported, 157 were partial and 14 were total bypasses. Forty-six of the

reported bypass events had durations of more than one day. Lake Pontchartrain was the ultimate receiving waterbody of the bypassed wastewaters.

The study indicated further that the nearshore areas, where wastewaters initially enter the lake, are most affected, at least in terms of elevated bacteria densities, by sewage discharges. Inordinately high bacteria densities impair primary contact recreation uses of the lake within the area extending from the shoreline to about 0.25 miles offshore in Jefferson and Orleans Parishes. A similar diminution of beneficial uses occurs at isolated locations along the north shore within about a 200-yard radius of where streams enter the lake. Generally, municipal wastewater discharges do not inhibit primary contact recreation uses of the more central portions of Lake Pontchartrain. The average of fecal coliform densities for samples taken at the approximate midpoints of both Lakes Maurepas and Pontchartrain suggest minimal bacterial contamination.

Nitrogen and phosphorus concentrations are reported to be significantly higher in areas fringing and surrounding Lake Pontchartrain than in the central portions of the lake (Stone, 1980). In particular, consistently higher nitrogen and phosphorus concentrations have been noted in Lake Maurepas, marshes adjacent to both Lakes Maurepas and Pontchartrain, and along Lake Pontchartrain's south shore. Also, algal blooms, which are indicative of excessive nutrient concentrations, often occur in Lake Maurepas and in Lake Pontchartrain near Pass Manchac and the Tangipahoa and Tchefuncte Rivers. Most of the marshes surrounding the lakes are considered to be hypereutrophic, or excessively nutrient rich. However, overall, Lake Pontchartrain is considered to be oligotrophic to mesotrophic, or nutrient deficient to moderately nutrient enriched. One theory advanced to explain Lake Pontchartrain's seeming resistance to lake-wide nutrient enrichment is that nutrients are continually removed from the water by settling sediment particles.

Enrichment of bottom sediments appears to be restricted to nearshore areas of pump station outfalls and where streams enter the lake.

In addition to permitted municipal wastewater discharges there are many unregulated sanitary waste discharges to the lakes. Drainage from septic tank systems and discharges from marinas and vessels also impact water quality in the lakes. Finally, discharges from the many camps located along the shoreline of the lakes and the banks of the tributary canals, streams, and bayous contribute to the wastewater load and have at least a minor impact.

3.8.2. **Urban and Agricultural Runoff**

Stormwater runoff from agricultural lands and urban areas may contribute significantly to the degradation of the quality of streams, bayous, lakes, and estuaries and can be the primary source of pollutant loading to receiving waters. The lakes area receives agricultural runoff from nearly 240,000 acres of cropland and over 470,000 acres of pasture located in the Lake Pontchartrain Basin (Louisiana Department of Natural Resources, 1980). Runoff from the state's two largest metropolitan areas - New Orleans and Baton Rouge - drains to the lakes area. Stormwaters are also discharged from the various urbanizing areas on the north shore of Lake Pontchartrain and along the east bank of the New Orleans-to-Baton Rouge industrial corridor. Stormwater runoff and sanitary wastewaters are similar in that the principal pollutants can be generally classified as oxygen demanding substances, plant nutrients, bacteria, and soils. Naturally, urban, agricultural, and sanitary wastewaters are dissimilar in terms of the nature, origin, and relative concentrations of these polluting substances. Also, unlike most sanitary wastewater discharges, agricultural and urban runoff are intermittent, rather than continuous, sources of pollutant loading to receiving waters.

A common characteristic of agricultural and urban runoff is that soil (sediment) is the most abundant pollutant contained in the discharge. The highest rates of soil loss occur on cropped agricultural land.

Approximately 12 percent of the land in the Lake Pontchartrain Basin that is subject to soil loss is used for crops. It is estimated that this cropland accounts for about 54 percent of the annual total soil loss in the basin (Louisiana Department of Natural Resources, 1980). The remaining soil loss is attributed to both rural and urban sources: pasture, forested areas, construction sites, unstable roadbanks and streambanks, surface mining areas, gullies, and canals. Only a small fraction of the soil displaced by agricultural and urban runoff actually contributes to stream pollution. About 5 percent of the total annual soil loss in the Pontchartrain Basin is eventually delivered to surface waters.

Sediments that do reach waterbodies are often carriers of chemical pollutants associated with the land use where the sediments originated. Nitrogen and phosphorus from commercial fertilizers are removed from cropland in stormwater runoff. Runoff from cropland also transports herbicides, fungicides, and insecticides in solution and in association with sediments. Studies indicate that only a small percentage of the total annual pesticide application is transported from cropland in stormwater runoff (U.S. Environmental Protection Agency, 1975). The production and use of many of the once heavily applied organochlorine insecticides have been banned for a decade or more. Still, trace concentrations of some of the long-lived organochlorine insecticides are occasionally detected in sediment, animal tissue, and, less frequently, in water samples taken from the lakes area.

The magnitude of fecal bacteria densities in agricultural wastewaters depends on the nature of the agribusiness operation and specific cultural practices. Typically, the highest bacteria densities occur in stormwater runoff from feedlot operations and where animal manures are applied directly to land to enhance soil fertility.

Besides sediments, urban runoff normally has high concentrations of other inert materials - trace metals, glass, rubber, and other debris - compared to runoff from agricultural lands or sanitary wastewaters. The

organic component of urban runoff is typically small compared to runoff from many types of agricultural land and substantially less than is characteristic of untreated or partially treated sanitary wastewater. Organics in urban runoff might consist of leaf litter, grass clippings, road oils and grease, bitumen leached from building roofs and street surfaces, and various anthropogenic organic compounds. The occurrence of man-made organics in urban runoff is dependent, in large measure, on the amount and nature of industrial activity in the urban area. Recent studies indicate that polynuclear aromatic hydrocarbons (PAH's), which are generally associated with fossil fuels combustion, use, and handling, are ubiquitous in the nearshore sediments of the Lake Pontchartrain south shore (Louisiana Department of Environmental Quality, 1984). The concentrations of PAH's and synthetic organic compounds measured, though indicative of anthropogenic pollution, were not considered deleterious to aquatic life nor consumers of seafood taken from the lake.

Normally, nitrogen, phosphorus, and pesticides are comparatively minor components of urban stormwater if not combined with sanitary waste discharges. Typically, nitrogen and phosphorus concentrations are highest in sanitary wastewater and pesticides are normally only present in trace concentrations. Fecal bacteria densities are typically high along the south shore of Lake Pontchartrain, probably because of the intermixing of urban runoff with sanitary waste discharges.

Often, due to heavy rainfall, discharges are a blend of sanitary wastewaters and stormwater runoff. Excessive infiltration and inflow of urban stormwater runoff into sanitary sewage collection systems can result in hydraulic overloading of sewage treatment facilities. The combined wastewater flows that are in excess of treatment plant capacity can wash out the microorganism population upon which the success of biological treatment processes depend. If significant microorganism loss were to occur, several weeks could be required for the lost population to be replenished and for the treatment process to restabilize. During the period of repopulation the biological treatment process would perform

suboptimally. Rather than risk such an event, treatment facility operators sometimes discharge excess combined wastewater flows bypassing all or part of the treatment plant.

3.8.3. Impacts of Loss of Wetlands Surrounding Lake Pontchartrain

The wetlands (swamps and marshes) adjacent to Lake Pontchartrain have experienced dramatic losses over the last 30-50 years due to both man's activities and natural causes. Much of the land area on the southern shore of Lake Pontchartrain presently occupied by Metairie, Kenner, and New Orleans East was once swamp and marsh. Vast portions of these areas have been drained and filled and now support industrial, commercial, and residential development. Some wetlands on the north shore have also been developed. Several marina-oriented developments such as Eden Isles and Venetian Isles have also been responsible for the loss of wetlands. In addition to the outright loss of wetland habitat resulting from these various developmental activities, impacts to water quality also result due to urban runoff and sewage introduced into the lake from these urban areas. In addition to urban development of the wetlands, other human activities, including canalization, leveeing, logging, dredging of navigation channels, bulkheading, and oil and gas activities have also caused loss of valuable wetlands.

Marsh and swamp losses have also resulted from erosion and saltwater intrusion in the area. These processes occur naturally, but are accentuated by man's activities, particularly the dredging of canals and channels.

This loss of wetlands adjacent to the lake has been implicated as one of the factors which has contributed to an apparent long-term increase in turbidity in the lake. Water which passes through swamps and marshes before entering the lake is less turbid because these wetlands tend to trap sediments. Water which enters the lake as urban runoff through

manmade outfall canals is not filtered and is often quite turbid, particularly following storms.

The most important impact of the loss of wetlands around the lake is due to the importance of wetlands to the overall biological productivity of the lake. It is the general consensus of fishery experts that fishery production is closely related to wetland acreage. In coastal Louisiana, the majority of commercially and recreationally important species are estuarine-dependent with juveniles using the estuaries and adjacent wetlands as nursery areas. Lake Pontchartrain is no exception. Use of this lake by fishery resources is discussed in detail in section 3.5 of the EIS and in Appendix D. Shrimp and menhaden yields have been directly correlated with the area of wetlands (Turner, 1979 and Cavit, 1979). Hinchee (1977) documented that the St. Charles Parish marshes on the south shore of the lake provide a very important nursery area for menhaden and other fish species.

Swamps and marshes produce large amounts of organic detritus that is transported into adjacent waterbodies. Detritus is a very important component of the estuarine food web. The role and importance of detritus in the estuarine food web has been well documented by Darnell (1961) and Odum et al. (1973).

3.8.4. Pollution From Outboard Motors

The exhaust products of internal combustion engines and unburned fuel from the combustion cycle are the principal water pollutants that result from the use of outboard motors. In areas where outboard motor usage is intense, exhaust emissions to the air can reduce local esthetic values. Subsequent fallout or washout of the emitted exhaust particulates from the air transforms the atmospheric pollutants to waterborne pollutants. Much attention has been directed toward lead as a hazardous waste product of the burning of leaded fuel. The amount of lead emitted directly into water from an outboard motor burning leaded gasoline is related to the

size of the motor and the speed of operation (National Academy of Sciences, 1973). Typically, these direct emissions increase with increased horsepower and the operating speed of the engine. About one-sixth to as much as one-third of the lead content of fuel consumed can be discharged. In the recent past leaded gasoline contained 0.7 grams of lead per liter. However, currently lead content is restricted to 0.1 grams per liter. In terms of water quality degradation, the total contribution of lead and other exhaust emissions from outboard motors is probably miniscule compared to quantities emitted from other sources.

According to the reference cited above, crankcase exhaust from two-cycle engines can discharge as much as 40 percent of the fuel used to the water in an unburned state; discharge of 10 to 20 percent of the fuel used unburned is common. Unburned fuel can impart an unpleasant odor and oily feel and appearance to the water's surface. Normally, high concentrations of unburned fuel on the order of 2 to 4 gallons per acre foot are required to impart off-flavors to aquatic life. Such high concentrations, i.e., greater than about 7 ppm, are not likely to occur over a large area except as a result of a significant spill. The typically very dilute unburned fuel is composed of a mixture of petroleum hydrocarbons that is, in general, readily degraded in the environment. Also, volatilization of unburned fuel from the water's surface is probably an important cleansing mechanism.

3.8.5. Operation of the Bonnet Carre' Spillway

Since its completion in 1931, the Bonnet Carre' Spillway has been used seven times for flood control. Intervals between openings have been as short as two years and as long as 23 years. The average interval between openings has been 7.7 years and the median interval 4.5 years. The expected frequency of spillway openings corresponds to the expected frequency of the 1.25 million cfs discharge on the Mississippi River at New Orleans.

This theoretical frequency is about once in 10 years; it only suggests that, over a very long period of time, 10 years will be the average interval between spillway openings. As is indicated above actual intervals between spillway openings will be quite variable. The length of time that the spillway has remained open during each flood has varied from 12 days to 74 days. Both the average and median duration of spillway openings has been about 44 days. Naturally, measurable water quality effects of spillway openings remain evident for short periods after cessation of floodwater discharges. Also, the duration of measurable water quality effects is very dependent on Amite, Tangipahoa, Tchefuncte, and particularly, Pearl River discharges before and concurrent with spillway openings, as well as after closure.

With each spillway opening, billions of gallons of floodwater enter the lake lowering salinity and water temperature, increasing turbidity, and precipitating other changes in water quality characteristics. Many tons of suspended solids, plant nutrients, and trace metals are discharged to the floodway and lake. In 1979, measured floodway discharge averaged 149,000 cfs during the 33-day period from 19 April through 21 May. At this average rate enough floodwater was discharged in about 16.5 days to replace the total volume of the lake. It has been estimated that it normally takes about 60 days for the normal total average streamflow to replace the total lake volume (Stone, 1980). A total of about 3,179 billion gallons of floodwater were discharged into the floodway during the 1979 event. Concurrent measurements of discharge and water quality parameters indicate that about 2.1 million tons of suspended solids, 21,000 tons of oxidized nitrogen ($NO2 + NO3 - N$), and 2,500 tons of phosphorus were discharged. Estimates of trace metal loadings include the following: arsenic - 27.3 tons, cadmium - 11.0 tons, copper - 96.3 tons, lead - 477.3 tons, nickel - 102.3 tons, zinc - 366.9 tons, and mercury - 1.2 tons.

While the physical effects of the spillway openings are normally dramatic, most of the measurable incremental changes in water quality

parameter concentrations are of short duration. Furthermore, as indicated previously, spillway openings are relatively infrequent, with sufficiently long periods between openings to allow the lake system to recover from any ill effects. It is widely believed that the periodic massive influx of nutrient rich floodwater, while manifesting negative impacts initially, have many post-diversion beneficial effects on the lake ecosystem. In fact, proposals are pending that would attempt to duplicate, albeit on a greatly reduced scale, the effects of spillway openings via freshwater diversions to enhance fish and wildlife resources.

The spillway has also been noted to influence Rangia populations. Several investigators have reported that spawning in Rangia is stimulated by osmotic stress. Rangia densities are generally higher near the mouths of tributaries where periodic influxes of fresh water occur.

3.8.6. Impacts of Shrimping (Bottom Trawling)

There has been considerable interest in the impacts of shrimping in coastal waters, including Lake Pontchartrain. Large numbers of commercial and recreational shrimpers utilize the lake, and the number of licensed commercial shrimpers has risen in recent years. Between 1976-1980, commercial shrimp licenses issued to residents of the parishes around the lake increased by an average of 15 percent per year, with a 27 percent increase in 1977. In 1981, numbers of licenses rose by another 27 percent (Thompson and Fitzhugh, 1985). In addition to commercial shrimpers, thousands of recreational shrimpers utilize the lake every year. Shrimping has been implicated as a factor involved in several apparent impacts which have occurred in Lake Pontchartrain.

It is well known that turbidity levels are elevated as a result of bottom disturbance created by passage of the trawl. Observation of aerial photographs clearly shows turbidity plumes associated with shrimping activities. The areal extent of the increased turbidities can vary greatly depending on the numbers of shrimping vessels and the sizes of

the trawls and boards (doors) of the trawls. The larger trawls disturb a greater area of water bottoms and the larger trawl boards penetrate deeper into the sediments. Increased turbidities as a result of shrimping are greatest during the first few weeks of shrimping seasons when large numbers of both commercial and recreational shrimpers trawl extensively. Little is known concerning the alteration of bottom sediments as a result of shrimping; however, it is known that extensive areas of the bottom are disturbed by this activity. Schubel et al. (1979) investigated shrimping as a source of suspended sediment in Corpus Christi Bay in Texas. The study showed that sediment disturbance in the bay as a result of shrimp trawling was 10-100 times greater than that caused by maintenance of navigation channels. Maximum concentrations of suspended sediments measured in the plumes of shrimp boats were comparable to those in the plumes from dredges operating in the same area.

Disturbance of bottom sediments by shrimp trawling also has the potential to release contaminants from the sediments into the water column. It is known that certain contaminants do occur in Lake Pontchartrain sediments (see Water Quality Section). The highest concentrations of contaminants appear to be nearshore areas, particularly in areas where tributaries and outfall canals enter the lake. In most areas of the lake, water depths are sufficient to allow shrimp boats, particularly smaller recreational vessels, to trawl very close to shore. If these boats trawl in areas of high contaminant concentrations, certain contaminants could be released into the water column.

Shrimp trawling can also cause destruction of submerged aquatic grassbeds. Passage of the trawls literally pull the submerged plants from the substrate. Repeated passage of shrimp trawls over grassbeds can denude the area. Mayer (1986) observed small shrimp boats trawling in the nearshore areas along the northeastern shore of the lake in May, 1985. Unfortunately, the area was not surveyed prior to the opening of the season and it was not possible to quantify impacts.

Bottom trawling for shrimp also destroys vast numbers of fish and invertebrates which are captured along with the shrimp (bycatch). With the exception of a few other desirable edible species (e.g., flounder, seatrout, blue crab, etc.) these other organisms are discarded back into the water. Nearly all of these are dead when they are returned to the water. The ratio of bycatch to shrimp varies considerably depending on the time of the year and the area in which the shrimping is conducted, but the bycatch is often considerable. Shrimping efforts are most concentrated during the first few weeks of brown shrimp season (usually in May) and at this time large numbers of estuarine-dependent species utilize Lake Pontchartrain as a nursery area. It is possible that shrimping serves to reduce populations of some of these species. On the other hand, it is believed by some that the discarded organisms ultimately contribute to the overall productivity of the system.

3.8.7. **Impacts of Other Permitted Activities**

Numerous types of activities require permits from the U.S. Army Corps of Engineers and other agencies before they can be implemented in the lakes area. These activities affect the lakes in a variety of ways. The New Orleans District has reviewed permit files for activities which have been permitted in the lakes and adjacent wetland areas. A list of types of activities and number of permits under each category is presented below.

Type of Activity	Number of Permits
Bulkheads	24
Bulkheads and fill	92
Dredging, bulkheads, and fill	116
Boat slips	69
Mooring facilities (marinas, wharves, etc.)	221
Fill projects	47
Levees	2

Submarine/aerial cable crossings	62
Pipelines	56
Dredging projects	51
Oil canals, channels, and slips w/structures	90
Dredge and fill activities	20
Crawfish ponds	2
Oil structures	26
Oil ring levees, board roads	19
Miscellaneous structures	69

All of these activities exert certain impacts on the system in which they are constructed. Although the impacts are often short term and localized, many of these activities cause long-term impacts related to habitat destruction and/or water quality degradation. The general impacts of the above permitted activities are discussed below.

Bulkheads, wharves, mooring facilities, boat slips, and similar structures cause several types of impacts. During construction, turbidity and other associated impacts often occur. Such structures can provide substrate for attachment of certain organisms; however, if they are constructed of treated materials, the potential exists for problems related to chemical contaminants. Depending on the size, location, and orientation of these structures, hydrological regimes can be altered.

Filling activities often destroy valuable wetland habitats. In addition to the direct habitat losses, the loss of wetlands causes decreased productivity in adjacent waterbodies. Subsequent development of filled areas often leads to a variety of secondary impacts.

Dredging activities cause a variety of primary and secondary impacts. Direct habitat losses occur due to the dredging. If the dredging is conducted in wetlands, valuable wetland habitats are converted to open water. If the dredging is conducted on existing waterbottoms, there is a direct loss of benthic habitat and organisms. Turbidity, reduced

dissolved oxygen concentrations, and release of nutrients and contaminants from the sediments often result from dredging and impacts vary with the magnitude of the dredging. Dredging of canals and channels often causes serious saltwater intrusion and increased erosion.

Construction of marinas often impacts large areas of wetlands and also causes the same short-term, localized impacts typical of other construction activities. A variety of secondary water quality impacts can also occur due to leakage of oil and gas from the vessels and from toxic substances both in the construction materials and in marine, antifouling paints used on the bottoms of the boats. Other amenities associated with large marinas also contribute to water quality problems.

Levees are one of the most damaging of man's activities. In addition to direct habitat losses due to construction, levees disrupt sheet flow and alter hydrological regimes. Due to their weight, they also often affect flow of water beneath the marsh surface. It has been well documented that marsh losses are very high adjacent to levees. These marsh losses ultimately affect the lake.

Submarine cables and pipelines destroy benthic habitat and cause localized impacts similar to those described above under dredging impacts. In some cases, these impacts occur periodically due to maintenance activities. These pipelines also present potential safety hazards and potential hazards to the environment in the event that they are ruptured.

Oil and gas exploration activities cause a variety of impacts. Impacts of canals and pipelines have been discussed above. Construction of platforms and tank batteries in the open waters of the lake destroys benthic habitat and causes turbidity and associated impacts. Salinities in the vicinity of tank batteries are sometimes elevated due to the higher salinity of formation waters. One of the most significant potential impacts of oil exploration and resultant structures is the possibility of a serious oil spill which could have grave biological implications.

3.8.8. **Impacts of Corps of Engineers Civil Works Projects**

In the Lake Pontchartrain vicinity, the Corps has three authorized projects excluding the Bonnet Carre' Spillway, which was discussed previously. There are two navigation projects - the Gulf Intracoastal Waterway (GIWW) and the Mississippi River - Gulf Outlet (MR-GO), and one flood control project, the Lake Pontchartrain Hurricane Protection project.

The impact of the GIWW on Lake Pontchartrain is minimal when considered on its own. The GIWW connects the Inner Harbor Navigation Canal (IHNC) to the eastern end of Lake Pontchartrain via Chef Menteur Pass and the Rigolets and to Lake Borgne via St. Thomas Pass. While providing a more direct shipping route, the GIWW in this reach had an immeasurably small impact on the salinity regime of Lake Pontchartrain considering the controlling depth of the channel and the salinity at the source of the hydraulic connection.

The influence of the MR-GO on Lake Pontchartrain has been more profound than that of the GIWW. The MR-GO is responsible for a change in the salinity regime of the lake and is identified with an anoxic zone originating near Seabrook (the location where the IHNC enters Lake Pontchartrain) which occurs in the lake during the summer. This zone is commonly referred to as the "dead zone". Salinities at the mouths of the Rigolets and Chef Menteur Pass, also contributors of saltwater into Lake Pontchartrain, are not as high as at the mouth of the IHNC. A comparison of pre and post MR-GO salinities at key stations in Lake Pontchartrain is shown in Table C-5 of Appendix C.

The Lake Pontchartrain Hurricane Protection project has had an insignificant direct impact on the water quality of the lake. This project would provide Standard Project Hurricane protection for the major urban areas in and immediately adjacent to New Orleans. The main

remaining feature of the plan would consist of providing protection to the populated portion of the east bank of St. Charles Parish.

Implementation of the project, which is currently under construction, would directly impact 213 acres of cypress-tupelogum swamp, 54 acres of brackish-saline marsh, 88 acres of scrub-shrub, and 351 acres of developed uplands which are primarily existing levees. The 213 acres of swamp and 54 acres of marsh would be converted to levees and borrow areas.

The levee alignment north of Airline Highway would provide some opportunity for development due to an additional increment of protection from the 100-year flood. However, the area has been and presently is being developed without the increased flood protection afforded by the proposed levee. The levee as proposed is designed with flow through culverts which would maintain the existing exchange of nutrients, water, and organisms between the wetlands north and south of Airline Highway. These culverts are to be gated so they can be closed during times of potential hurricane flooding.

4. LIST OF PREPARERS

The following people were primarily responsible for preparing this Environmental Impact Statement

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5. PUBLIC INVOLVEMENT

5.1. PUBLIC INVOLVEMENT PROGRAM

Two scoping meetings were held to allow interested parties to express their concerns regarding shell dredging and to assist in identification of impacts and alternatives to be addressed in the EIS. The first meeting was held in Morgan City, Louisiana on June 24, 1986, where the comments of 158 registered attendees were recorded. The second meeting, held in New Orleans, Louisiana on June 26, 1986, attracted 145 registered attendees, whose comments and concerns were also recorded. Participants were also informed that written comments would be gathered through July 11, 1986. A total of 463 comments were recorded from the scoping meetings and numerous concerns were also submitted in 16 scoping letters. It should be pointed out that comments received at these meetings pertained to both the clam shell dredging addressed in this EIS as well as the oyster shell dredging which is being addressed in a companion EIS. The comments were analyzed and a Scoping Document was prepared and distributed to all scoping meeting participants on August 9, 1986. The comments were carefully reviewed to formulate a list of significant concerns/issues that have been addressed in this EIS. The following alternatives were identified during the scoping process and considered during preparation of the DEIS.

<u>No Federal Action (Permit Denial)</u> - This alternative assumes that the permit(s) would be denied and all shell dredging activities would cease. As part of the analysis under this alternative, other materials which could be used as an alternative to shells for their various important uses were investigated. Alternative materials identified by the public during the EIS process included limestone, gypsum waste, spent bauxite, and sand. Other materials were also analyzed.

Renew Permits With Existing Conditions - This alternative assumes that shell dredging activities would continue under existing conditions, i.e., as currently permitted and regulated by all agencies involved.

Renew Permits With Additional Restrictions - This is a generic alternative under which a number of possibilities exist. Three major categories were developed under this alternative and include additional restrictions on areas available for dredging, additional restrictions on dredging intensity, and additional restrictions on the method by which the dredged material is discharged.

Renew Permits With Reduced Restrictions - Under this alternative, additional restrictions on areas available for dredging, dredging intensity, and modifications to dredge discharge were considered.

An analysis of the aforementioned alternatives is presented in the Alternatives Section (Section 2) of this EIS.

A Notice of Intent to prepare this EIS was published in the Federal Register on July 7, 1986. During preparation of this EIS, a number of formal and informal meetings have been held with a variety of interested parties, including personnel from other agencies, universities, consultants, members of the public, and members of the shell dredging industry. Most of these individuals have been involved with the shell dredging issue for some time. At most of these meetings, shell dredging in both the lakes area and the gulf coast area were discussed. The meetings were held for two primary reasons. First, to find out if these people had any published or unpublished information that would be of value in preparation of the EIS and second, to take advantage of their personal knowledge and opinions concerning the impacts of shell dredging in order to develop an overall approach to impact assessment. The following is a list of primary meetings which have been held with individuals knowledgeable regarding shell dredging.

Individual (s)	Affiliation	Date
Dr. Jack Taylor	Taylor Biological Co.	8 Aug 86
Mr. Don Palmore	Dravo Industries	8 Aug 86
Mr.Gerry Bodin	USFWS	27 Aug 86
Dr. Bruce Thompson	LSU - CWR	28 Aug 86
Mr. Mike Schurtz	DEQ	28 Aug 86
Mr. Dugan Sabins	DEQ	28 Aug 86
Mr. John Tarver	LDWF	29 Aug 86
Mr. Mike Schurtz	DEQ	29 Aug 86
Mr. Dugan Sabins	DEQ	29 Aug 86
Mr. John Demond	DNR - CMS	29 Aug 86
Mr. Darryl Clark	DNR - CMS	29 Aug 86
Mr. Bo Blackmon	DNR - CMS	29 Aug 86
Ms. Barbara Benson	DNR - CMS	29 Aug 86
Dr. Mike Porrier	UNO	2 Sep 86
Dr. Bill Barnett	Loyola	3 Sep 86
Mr. Don Palmore	Dravo Industries	3 Sep 86
Dr. Gary Childers	SLU	8 Sep 86
Dr. Bob Hastings	SLU	8 Sep 86
Mr. Jim Blackburn	Attorney	15 Sep 86
Mr. Harold Schoeffler	Save Our Coast	15 Sep 86
Mr. Alfred Hitter, Jr.	Save Our Coast	15 Sep 86
Mr. Pete Juneau	LDWF	16 Sep 86
Mr. Gerry Bodin	USFWS	16 Sep 86
Dr. Walter Sikora	LSU	19 Sep 86
Dr. Jean Sikora	LSU	19 Sep 86
Dr. Hinton Hoese	USL	16 Oct 86
Dr. Daryl Felder	USL	16 Oct 86
Mr. Michael Osborne	Attorney	4 Dec 86
Mr. Harold Schoeffler	Save Our Coast	4 Dec 86

On Tuesday, June 2, 1987, at 7:00 p.m., the primary public hearing was held to accept public comments regarding the draft environmental impact statement (DEIS) for clamshell dredging in Lakes Pontchartrain and Maurepas, Louisiana. Comments regarding the permit extension requests for the three shell dredging companies were also accepted at the meeting. The meeting was held at the U.S. Army Corps of Engineers, New Orleans District Headquarters Building, District Assembly Room. The meeting was presided by Colonel Lloyd K. Brown, District Engineer, New Orleans District and Dr. Charles G. Groat, Assistant to the Secretary of the Louisiana Department of Natural Resources (DNR). Colonel Brown and Dr. Groat introduced the members of their respective staffs in attendance at the hearing. On Tuesday, May 26, 1987, at 7:00 p.m. a public hearing was held in Morgan City Louisiana. Although the primary purpose of that meeting was to accept comments on the DEIS for oyster shell dredging in Atchafalaya Bay and adjacent waters, comments on shell dredging in Lakes Pontchartrain and Maurepas were also accepted for the convenience of those who could not attend the New Orleans public hearing.

Colonel Brown explained that the purpose of the meeting was to obtain comments on the DEIS and obtain views for use by the Corps and DNR in evaluating the requests for the permit extensions. He then discussed the order of business for the public hearing and explained how the public views would be used to develop the final EIS. Dr. Groat explained that coastal use permits from DNR are also required for shell dredging and that he and his staff were also very interested in the views of the public regarding the DEIS and the permit requests. Colonel Brown showed a brief slide presentation regarding shell dredging and then opened the floor for comments.

A total of 225 registered individuals attended the June 2, 1987, meeting and 50 people presented formal statements regarding the DEIS and/or permit requests. Of these 50 speakers, 40 spoke in favor of shell dredging and 10 spoke against shell dredging. Most of the individuals who spoke in support of shell dredging were involved with the shell

dredging industry or related industries that depend to some extent on the shell dredging industry for their livelihood. Those who spoke against shell dredging included representatives of environmental groups and concerned individuals. A complete transcript of the public hearing can be obtained from the Corps at a cost of about $20.00.

A number of issues and concerns were identified by those who spoke at the meeting. The majority of the issues and concerns regarding shell dredging were the same ones that have existed for a number of years. No significant new issues surfaced at the meeting.

The proponents of shell dredging highlighted the socio-economic benefits of the industry including employment, tax revenues, and social and emotional well-being within the community. The importance of the shell dredging industry to other related industries such as shipbuilding and repair facilities, marine supply companies, hardware stores, trucking companies, construction companies, and other industries dependent to some extent on the shell dredging industry was discussed by a number of speakers.

Those speakers concerned over adverse environmental impacts associated with shell dredging identified several major areas of concern regarding impacts to water quality and biological and botanical resources. These include concern over turbidity, release of contaminants and nutrients from the sediments, and impacts to benthos, fisheries, endangered species, grassbeds, phytoplankton, and other resources.

In addition to the concerns expressed at the public hearings, 21 comment letters, some of which are very detailed and extensive, were received during the comment period on the DEIS (Volume 2). The concerns expressed in these letters are generally the same as those that surfaced at the public hearing. The views and concerns expressed at the public hearing and in the comment letters have been addressed either by incorporating changes in the final EIS or by responding in detail to the comment letters (Volume 3).

No new alternatives were added as a result of public comments on the DEIS. Several agencies made the comment that cessation of shell dredging in Lake Maurepas should be carried as a separate alternative. In response to those comments (Volume 3) it was emphasized that closure of Lake Maurepas does not have to be carried as a separate alternative in order for the Corps to consider cessation of shell dredging in that lake. The existing permits and the permit requests are for both Lakes Maurepas and Pontchartrain. The Corps can restrict shell dredging in any portion of this area as a condition of the permits. Information contained in the FEIS will play a major role in making decisions on areas to be permitted or denied.

5.2. REQUIRED COORDINATION

The draft EIS was furnished to federal agencies, state agencies, and other interested parties for their review. Circulation of the draft EIS and this final EIS report is in accord with the required coordination under the National Historic Preservation Act and the National Environmental Policy Act.

5.3. STATEMENT RECIPIENTS

The U.S. senators and congressmen, federal, and state agencies listed below were sent copies of the draft EIS and appendixes. Other listed parties as well as numerous individuals not shown on the list were sent at least a Notice of Availability. Copies of the draft EIS were furnished to the libraries listed below to provide interested parties further opportunity to review the document.

Honorable J. Bennett Johnston

Honorable John Breaux

Honorable Lindy (Mrs. Hale) Boggs

Honorable James A. Hayes

Honorable Jerry Huckaby

Honorable Robert L. Livingston

Honorable Clyde Holloway

Honorable Richard Baker

Honorable William "Billy" Tauzin

Honorable Buddy Roemer

FEDERAL AGENCIES

Department of the Interior, Office of Environmental Project Review

US Environmental Protection Agency, Regional EIS Coordinator, Region VI

US Environmental Protection Agency, Administrator

US Department of Commerce, Joyce M. Wood, Director, Office of Ecology and Conservation

US Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Southeast Region

National Marine Fisheries Service, Mr. Donald Moore, Environmental Assessment Branch

US Department of Agriculture, Washington, D.C.

US Department of Agriculture, Southern Region, Regional Forester, Forest Service

US Department of Energy, Director, Office of Environmental Compliance, Washington, D.C.

Federal Emergency Management Administration, Washington, D.C.

Soil Conservation Service, Harry S. Rucker, State Conservationist

US Department of Transportation, Deputy Director for Environmental and Policy Review

Federal Highway Administration, Division Administrator

US Department of Health and Human Services, Washington, D.C.

US Department of Health and Human Services, Atlanta, Georgia, Stephen Margolis, Ph.D.

US Department of Housing and Urban Development, Regional Administrator, Region VI

Advisory Council on Historic Preservation, Washington, D.C.

Advisory Council on Historic Preservation, Golden, CO

STATE AGENCIES

Louisiana Department of Health and Human Resources, Office of Health Services and Environmental Quality

Louisiana Department of Transportation and Development, Office of Public Works, Assistant Secretary

Louisiana Department of Highways, Mr. Vincent Pizzolato, Public Hearings and Environmental Impact Engineer

Louisiana Department of Wildlife and Fisheries, Mr. Maurice B. Watson, Ecological Studies Section

Louisiana Department of Wildlife and Fisheries, Secretary

Louisiana Department of Natural Resources, Office of Environmental Affairs

Louisiana Department of Natural Resources, Division of State Lands, P. O. Box 44396

Louisiana Department of Natural Resources, Coastal Resources Program

Louisiana Department of Commerce, Research Division, Mrs. Nancy P. Jensen

Louisiana Department of Culture, Recreation, and Tourism, State Historic Preservation Officer

Louisiana Department of Culture, Recreation, and Tourism, Office of State Parks

Louisiana Department of Natural Resources, Office of Environmental Affairs

Louisiana Department of Natural Resources, Office of Forestry

Louisiana State Planning Office, Ms. Joy Bartholomew,
Policy Planner

Louisiana State University:, Center for Wetland Resources,
Dr. Jack R. Van Lopik

Louisiana State University, Department of Geography and
Anthropology, Curator of Anthropology

Louisiana State University, Coastal Studies Institute,
Library

Department of Natural Resources, Division of State Lands,
P. O. Box 44214

Governor's Coastal Protection Task Force, Gerald Bordelon

LIBRARIES

New Orleans Public Library

Iberia Parish Public Library Department

St. Mary Parish Library

Vermilion Parish Library

Terrebonne Parish Library

Louisiana State University, Coastal Studies Institute Library

Earl K. Long Library, University of New Orleans

Tulane University Library

OTHER INTERESTED PARTIES

Save Our Coast

Environmental Defense Fund

Orleans Audubon Society, Mr. Barry Kohl

Manchac Fisherman's Association

Ecology Center of Louisiana, Inc., J. Vincent, President

Mr. Oliver Houck, Tulane Law School

Mr. Clifford Danby

Regional Representative, National Audubon Society, South Western Regional Office

Field Research Director, National Audubon Society

Thibodaux-Houma Sierra Club, c/o Bob Blair

Delta Chapter, Sierra Club, New Orleans

Mr. Michael Halle

Chappepeela Group Sierra Club (Florida Parishes), c/o Hulin Robert

National Wildlife Federation, Washington, D.C.

Randy P. Lanctot, Executive Director, Louisiana Wildlife Federation

Wildlife Management Institute, South Central Representative Mr. Murray T. Walton

The Conservation Foundation, Washington, D.C.

James W. Keeton, Trout Unlimited, San Antonio, TX

Natural Resources Defense Council, Inc.

League of Women Voters of the U.S.

Slidell Sportsmen's League

Mr. Donald Landry, President, South Louisiana Environmental Council

Mr. Sidney Rosenthal, Jr., Field Agent, The Fund for Animals, Inc.

Environmental Impact Officer, Jefferson Parish, Louisiana

Captain O.T. Melvin, Larose, Louisiana

John M. Anderson, National Audubon Society, Abbeville, Louisiana

Terrebonne Parish Police Jury, Waterways and Permit Committee

Gulf States Marine Fisheries Commission

Mrs. Roberta A. Scull, Government Documents Department, Library, LSU

Government Documents Division, Earl K. Long Library, UNO

Sea Grant legal Program

Chairman, Environmental Committee, Bonnet Carre' Rod and Gun Club

Lake Pontchartrain Sanitary District

Lafayette Natural History Museum and Planetarium

Mr. J. H. Jones, Professor, Department of Economics and Finance, College of Administration and Business, Louisiana Tech University

Mr. C. C. Lockwood, Wildlife Photographer, Cactus Clyde Productions

Mr. R. W. Collins

Mr. Freddy Trosclair, Jr.

Mr. Joel D. Patterson, Manager, Environmental Affairs Section, Middle South Services, Inc.

Mr. Ronnie W. Duke, T. Baker Smith & Son, Inc.

Mr. Warren Mermilliod, Marine Advisory Agent, Louisiana Cooperative Extension Service, U.S. Department of Agriculture, LSU

Mr. George Pivach, Jr.

Mr. Anatoly Hochstein

Mr. Chris M. Piehler

Mr. James Wattingny

Ms. Wilma Subra

Dr. Robert Hastings

Mr. Charlie Winder

Mr. Marshall Powell

Mr. Horace Thibodaux

Mr. Ron Sonier

Ms. Janet Phillpott

Mr. Pete Wren, Jr.

Mr. Elliott L. Kipp

Mr. Herbert Miller

Mr. Frank Riess

Dr. Don Resio

Mr. Joseph Vincent

Ms. Nelda Stanley

Ms. Ginney Staib

Mr. Barney Barrett

Mr. Vince Guillory

Ms. Gretchen Hebert

Mr. Chris Madden

Ms. Charlotte Fremaux

Ms. Sharon Balfour

Mr. Donal Wallis

Dr. Rezneat Darnell

Mr. John Rombach

Ms. Joanne Brandt

Mr. Corky Perrett

Mr. Richard Hayes

Mr. Ladd Brown

Mr. Herbert Miller

Mr. Hal Reinstra

Mr. Michael Osborne

Mr. Jim Brabner

Mr. James Blackburn

Mr. Gene Weber

Dr. Donald Pavy

Mr. Harold Schoeffler

Mr. Brandt Savoie

Mr. Ernie Landerie

Ms. Susan Clade

Mr. Richard Carriere

Mr. John Demond

Dr. Mary Curry

Dr. Rod Emmer

Steimle and Associates

Dr. John Taylor

Mr. Robin Durant

Mr. Pierre DeGruy

Mr. George Douglass

Dr. Michael Poirrier

Dr. Bruce Thompson

Dr. Walter Sikora

Dr. Jean Sikora

Dr. William Barnett, Jr.

Mr. Dugan Sabins

Mr. Johnnie Tarver

Mr. James R. Boyle

Mr. Joseph Leblanc

5.4. LETTERS OF COMMENT ON THE DRAFT EIS

Letters of comment on the draft EIS were received from the following:

FEDERAL AGENCIES

U.S. Department of Housing and Urban Development

U.S. Department of Health and Human Services, Centers for Disease Control

U.S. Department of Commerce, National Marine Fisheries Service

Federal Emergency Management Agency

U.S. Department of the Interior

U.S. Environmental Protection Agency

STATE AGENCIES

Louisiana Department of Culture, Recreation, and Tourism

Louisiana Department of Wildlife and Fisheries, Fur and Refuge Division

Louisiana Department of Wildlife and Fisheries, Secretary

State of Louisiana, Department of Justice, Attorney General's Office (two letters)

OTHERS

James B. Blackburn, Jr., Attorney for Save Our Coast

Orleans Audubon Society

Osborne & McComiskey, Attorney for the plaintiffs in Louisiana vs. Lee

Sierra Club, Honey Island Group

Mark Schexnayder

Louisiana Synthetic Aggregates, Inc.

Louisiana Shell Producers Association

Dr. Rezneat M. Darnell, Texas A&M University

Mr. Richard Carriere, Save the Lake Action Committee

Mr. John R. Rombach

The agencies and individuals that commented on the draft EIS will all receive a copy of the final EIS and the Public Views and Responses (Volume 2). Certain other interested parties will also receive copies of the document or a notice of availability.

5.5. PUBLIC VIEWS AND RESPONSES

Twenty-one comment letters were received concerning the draft EIS. Issues and concerns expressed in these letters were responded to either by adding information to the FEIS or providing a response in the Volume 2 (Public Views and Responses). This appendix will be sent to everyone who receives a copy of the final EIS and is considered to be an integral part of the FEIS.

AD-A186 640 CLAM SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS 3/5
LOUISIANA VOLUME (U) ARMY ENGINEER DISTRICT NEW
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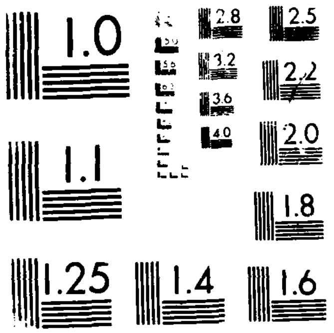
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7. INDEX

Subject

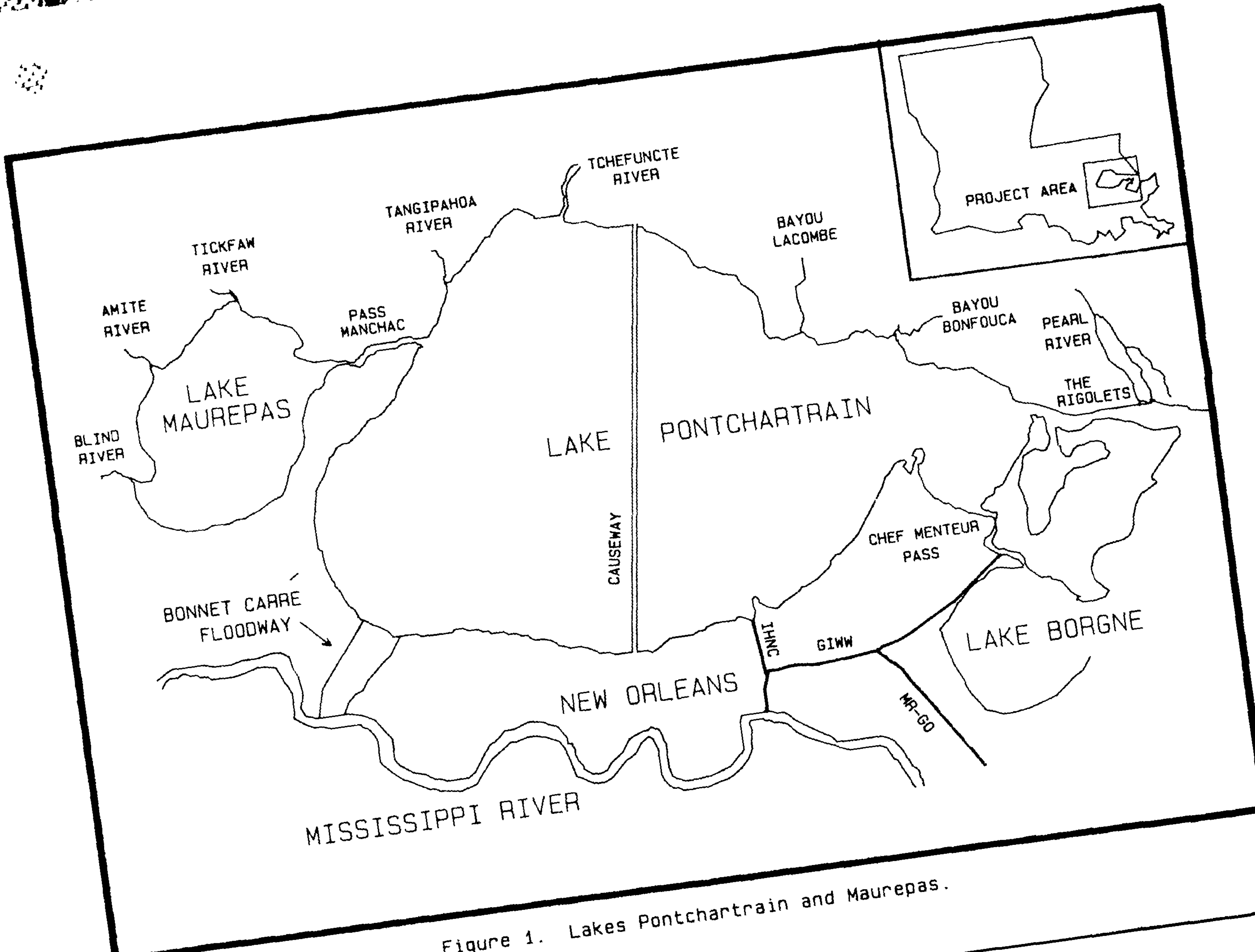


Figure 1. Lakes Pontchartrain and Maurepas.

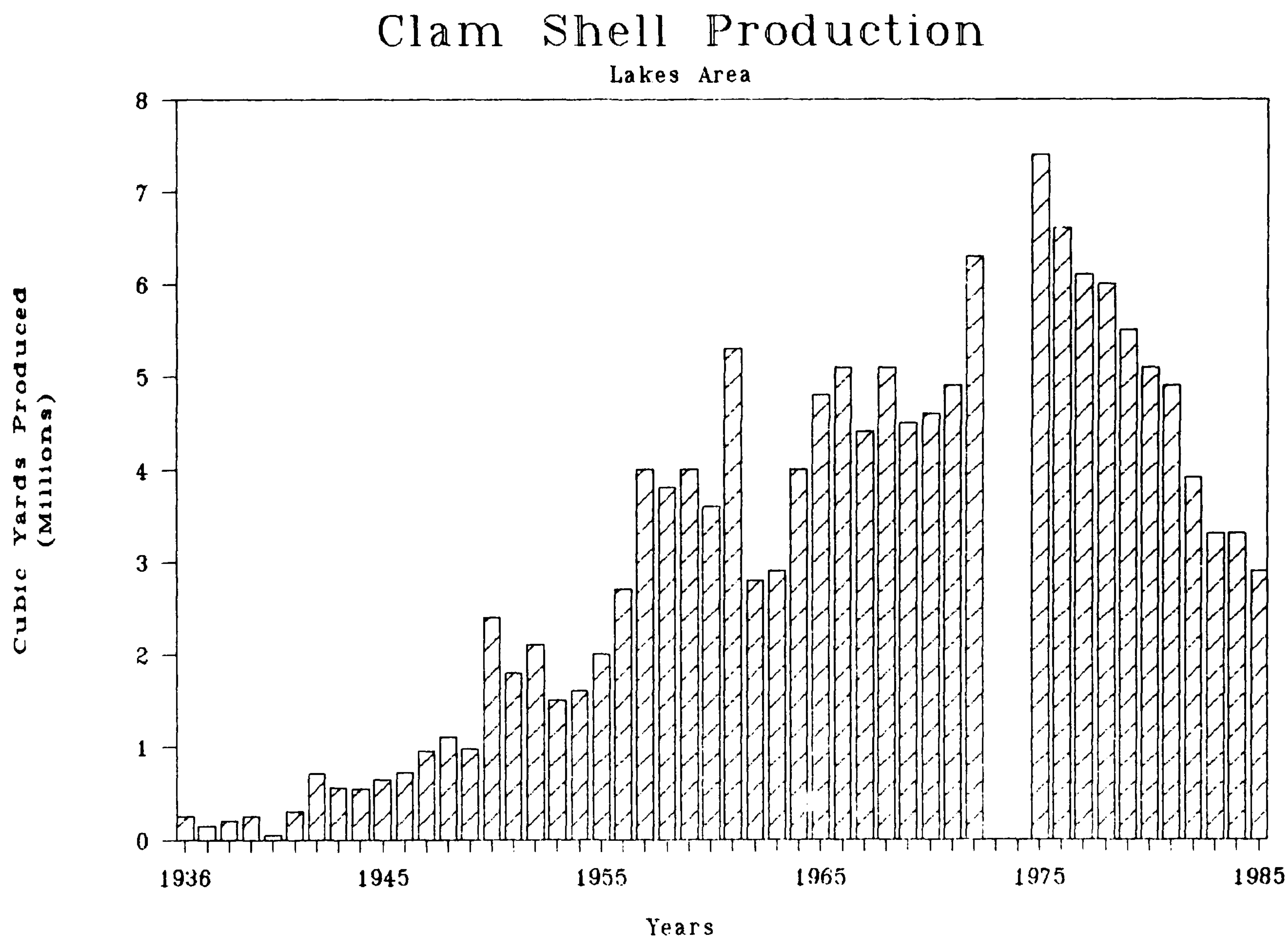


Figure 2. Clam shell production from 1936-1985.

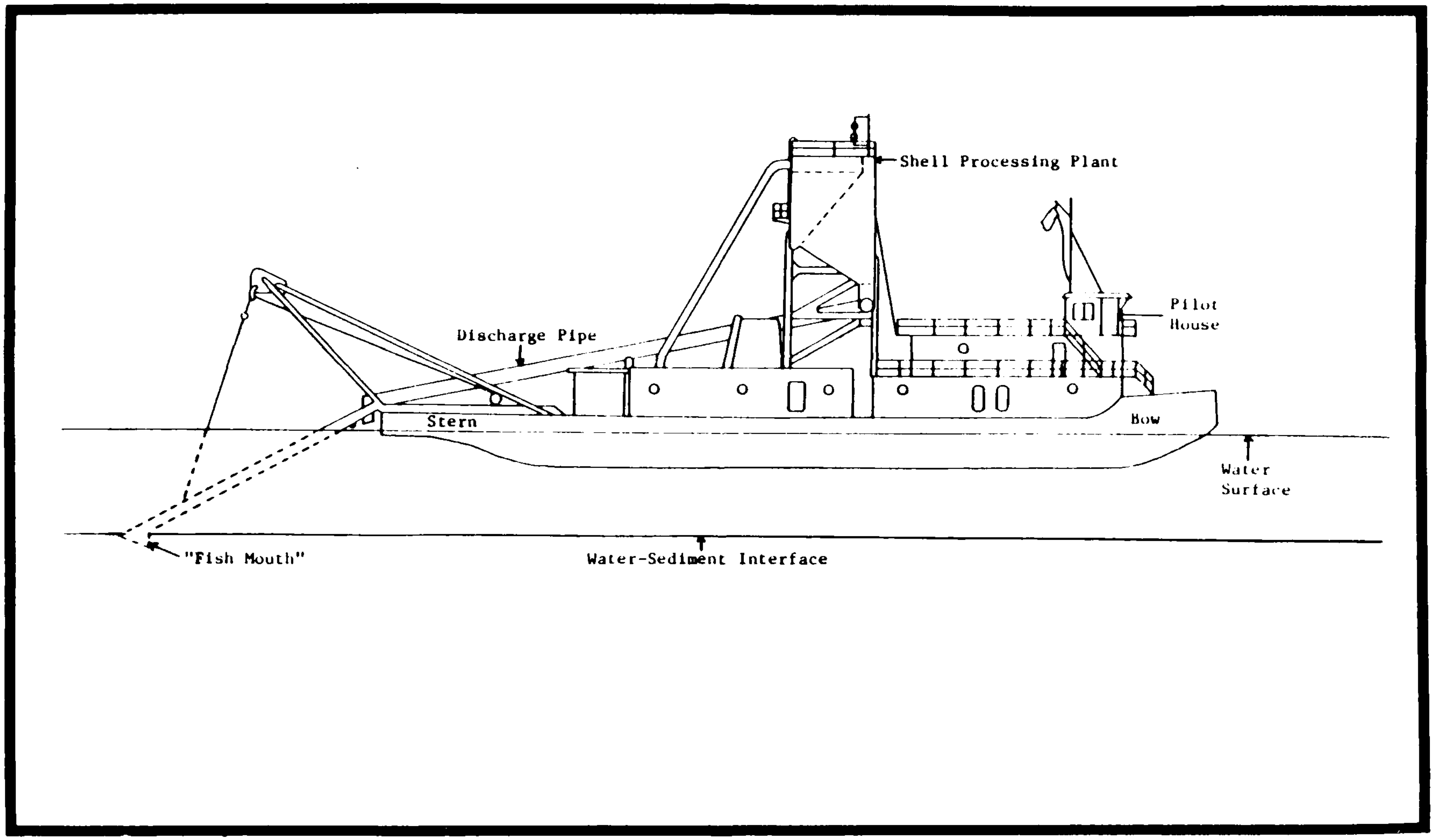


Figure 3. Diagram of a typical dredge used to harvest clam shells from Lakes Pontchartrain and Maurepas.

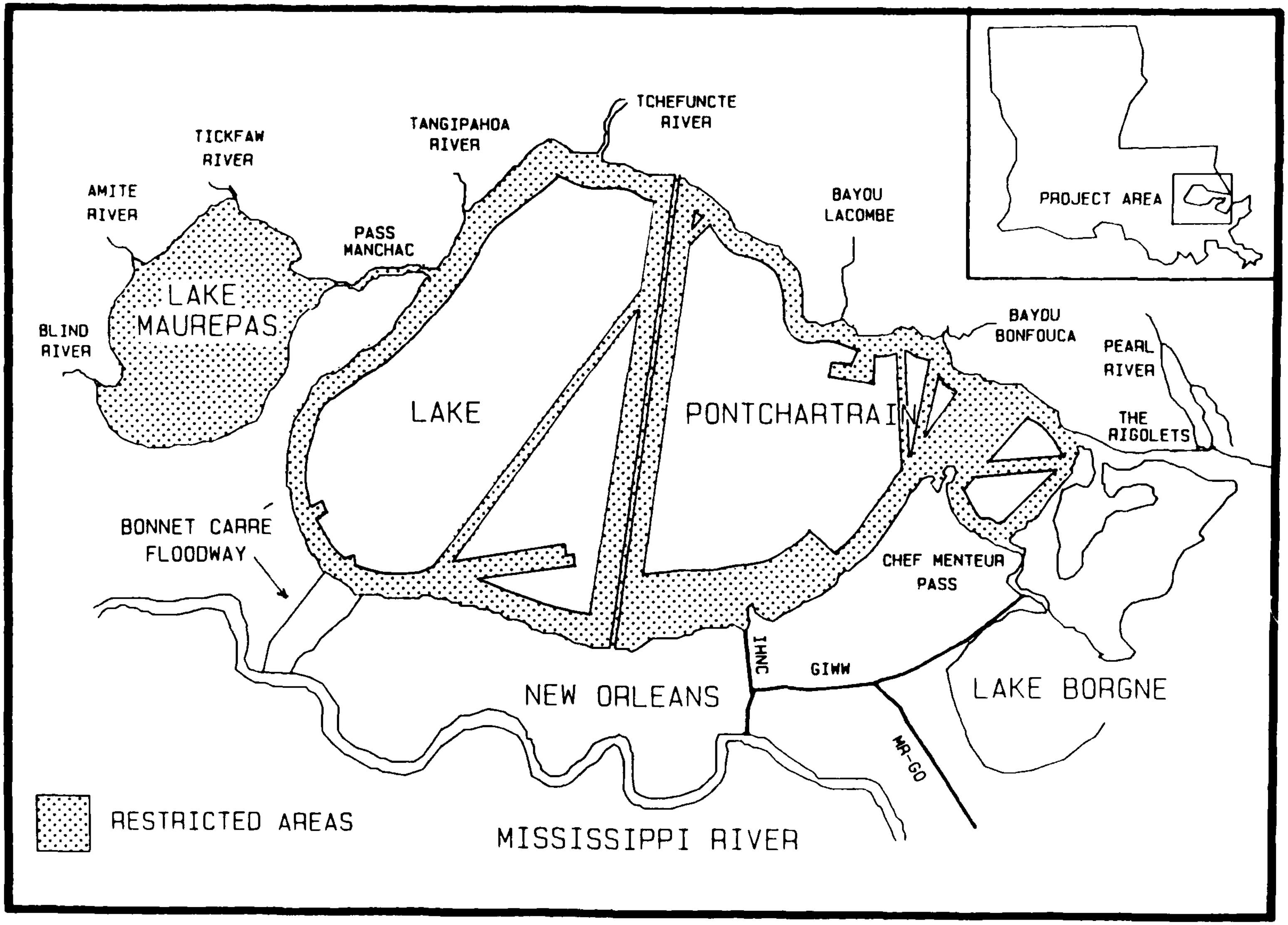


Figure 4. Areal restrictions in Lakes Pontchartrain and Maurepas.

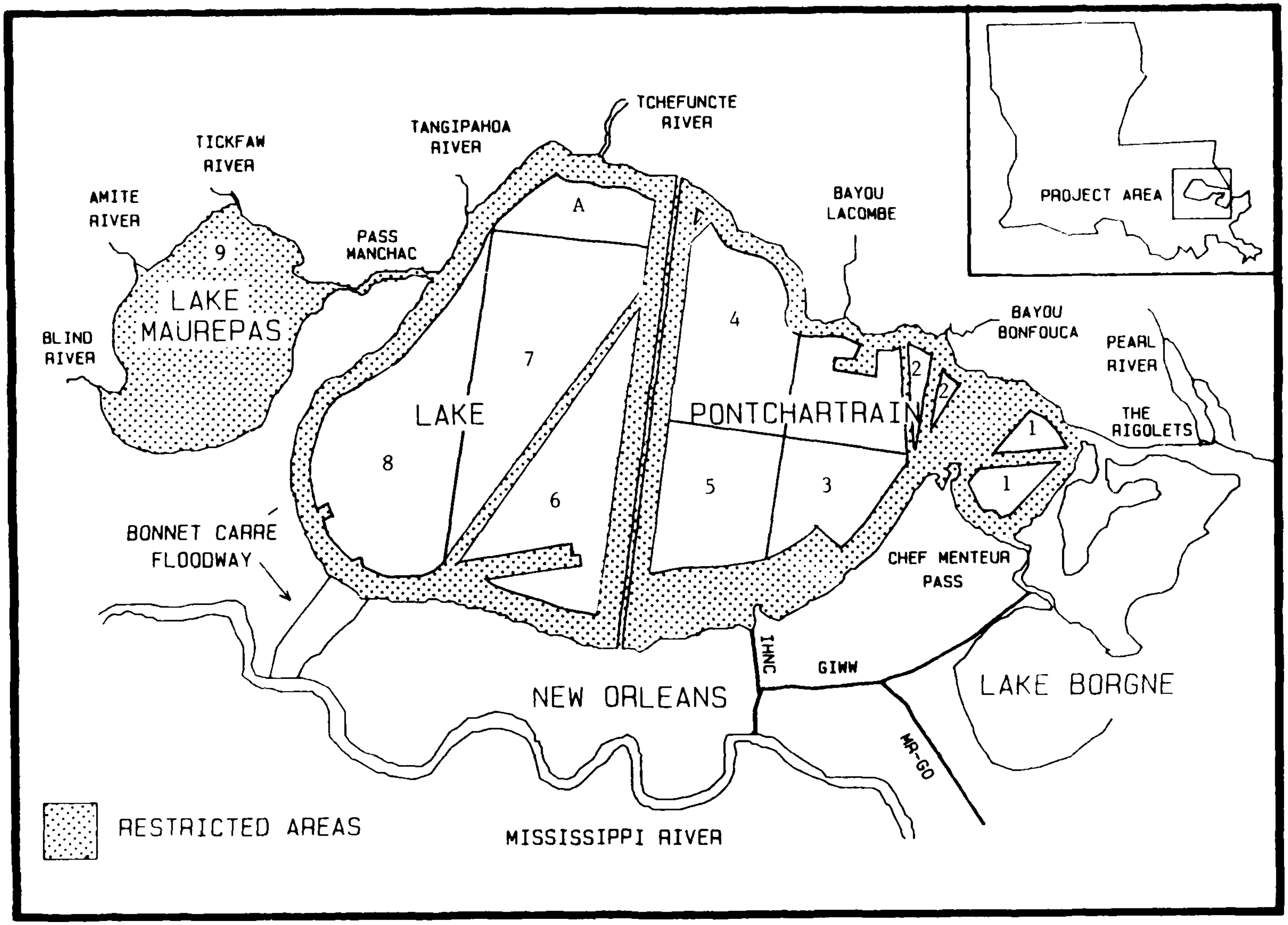


Figure 5. Shell dredging zones in Lakes Pontchartrain and Maurepas.

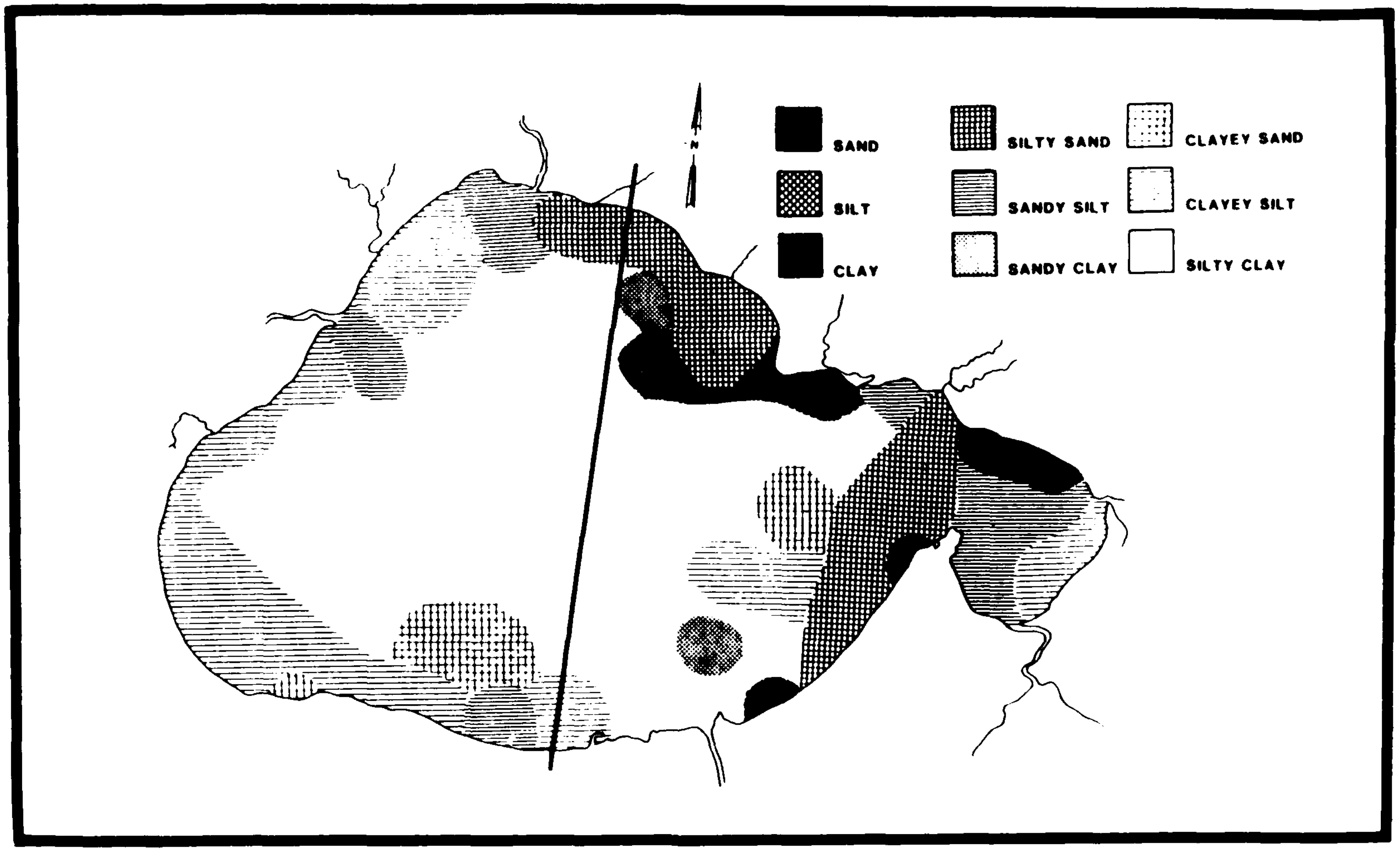


Figure 6. Distribution of sediment types in Lake Pontchartrain (Bahr et al., 1980).

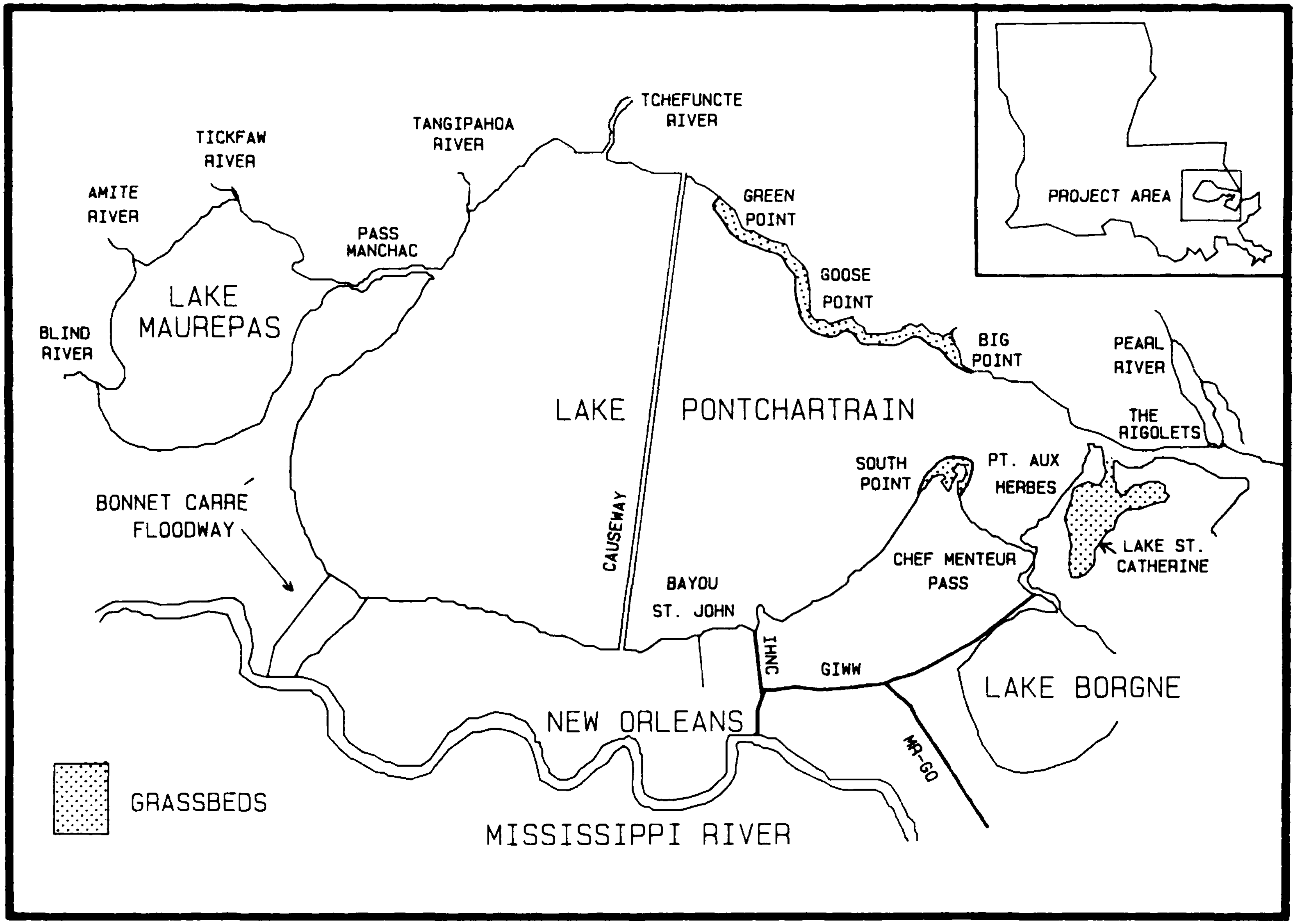
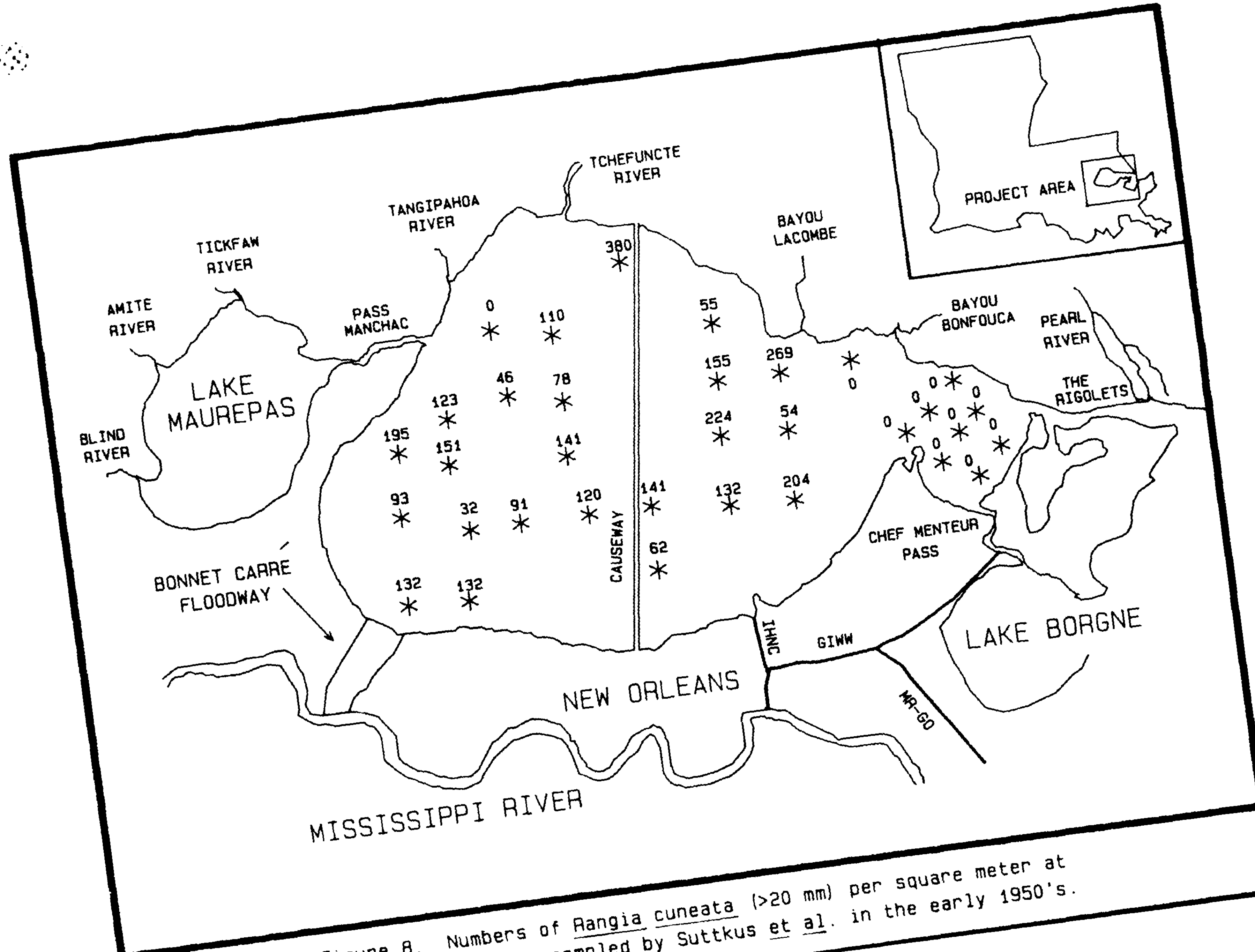


Figure 7. Primary concentrations of grassbeds in Lake Pontchartrain.



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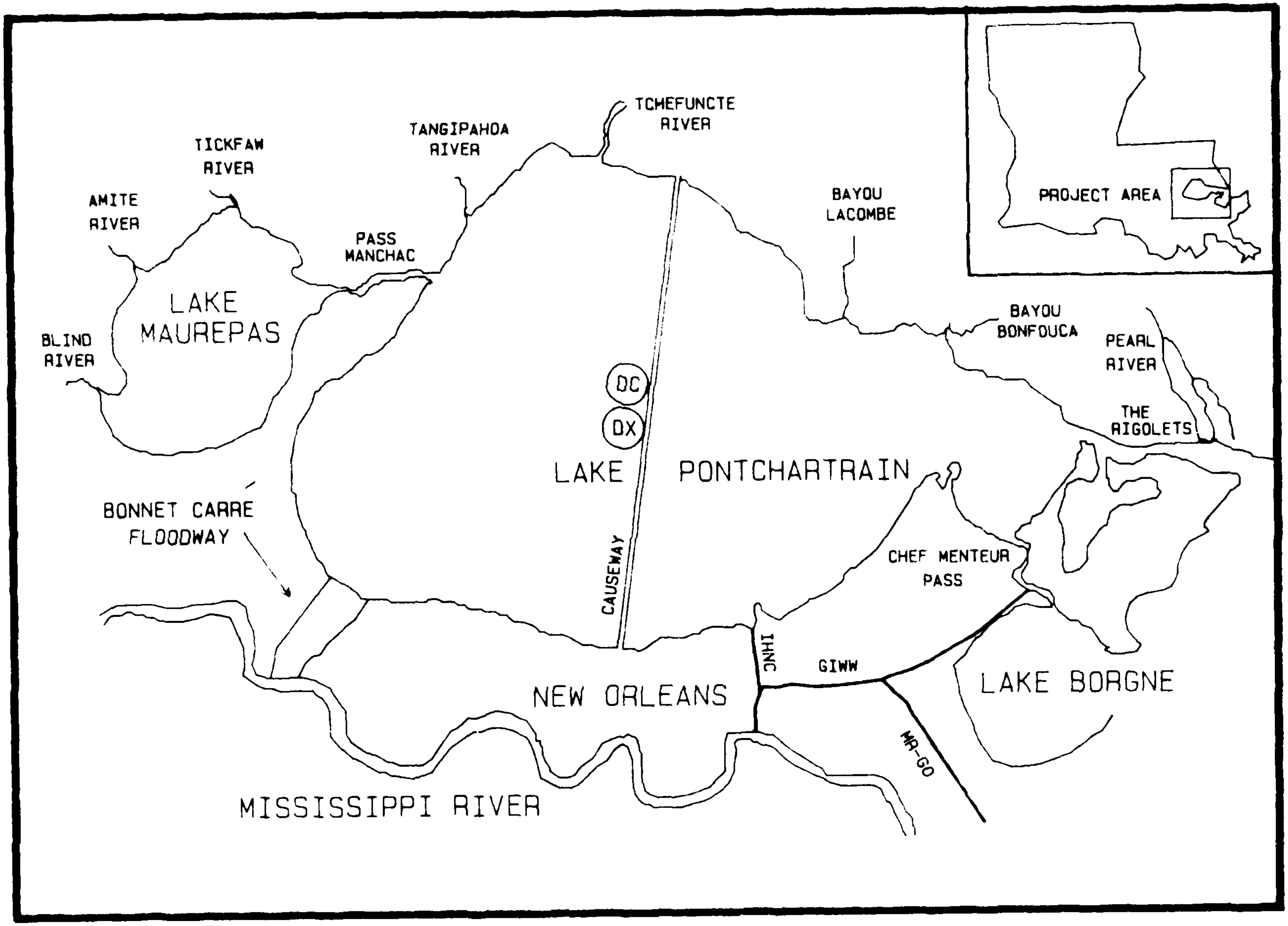

Figure 9. Experimental dredge station (DX) and control station (DC) used by Sikora et al. (1981).

APPENDIX A

BIOLOGICAL ASSESSMENT OF IMPACTS OF SHELL DREDGING
ON THREATENED AND ENDANGERED SPECIES

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APPENDIX A

BIOLOGICAL ASSESSMENT OF IMPACTS OF SHELL DREDGING
ON THREATENED AND ENDANGERED SPECIES

Introduction

This appendix includes the Biological Assessment of Threatened and Endangered Species. It also includes copies of correspondence between the U.S. Army Corps of Engineers, New Orleans District, and the U.S. Fish and Wildlife Service and National Marine Fisheries Service concerning threatened and endangered species present in the area affected by shell dredging and the impacts of the activity on these species.

BIOLOGICAL ASSESSMENT OF IMPACTS OF SHELL DREDGING ON THREATENED AND ENDANGERED SPECIES

Lakes Pontchartrain and Maurepas, Louisiana

Introduction

This assessment addresses the threatened and endangered species which may be affected by clam shell (Rangia) dredging in Lakes Pontchartrain and Maurepas. Although Lake Maurepas is currently closed to dredging, it is possible that it could be re-opened in the future.

Clam shells are dredged using a sweeper-type dredge equipped with a suction head known as a "fish-mouth" which works the upper 20 to 30 inches of the bottom sediments. The dredges are either self-propelled or pushed by tugboats in a circular pattern at an average speed of approximately 2 mph until the rate of shell recovery falls below economic feasibility. The material is collected by hydraulic suction and pumped aboard the dredge. The shells are extracted from the sediment by washing and the sediments are discharged overboard back into the water. The bottom configuration immediately following dredging is a trench about 2 to 3 feet deep and 4 to 5 feet wide.

Two species of sea turtles have been identified by the National Marine Fisheries Service as species which may be impacted by the proposed activity. Kemp's (Atlantic) ridley (Lepidochelys kempi) is listed as endangered and the loggerhead turtle (Caretta caretta) is listed as threatened under the Endangered Species Act.

Information on sea turtles in coastal Louisiana in general is sparse. However, this assessment is the result of conversations and correspondence with knowledgeable persons as well as a review of published and unpublished literature. Historical and recent occurrence of the Kemp's ridley and the loggerhead turtle in the two lakes is summarized, and the potential impacts are discussed.

Kemp's Ridley (Lepidochelys kempi)

The major nesting beach of the Kemp's ridley is located at Rancho Nuevo, Mexico, 30 km south of the Rio Grande, with sporadic nesting along the Texas coast. Females arrive in small aggregations known as arribadas from mid-April through August (Rabalais and Rabalais 1980). Population declines of the ridley have been attributed to egg stealing on the localized nesting beach, capture of diurnal nesting females, fishing and accidental capture in shrimp trawls (Fuller 1978, Pritchard and Marquez 1973). Nesting of ridleys in coastal Louisiana is insignificant. However, Hildebrand (1981) mentions that Isle Derniere may have been a nesting place prior to the major hurricane of 1856 which destroyed favorable nesting habitats. Viosca (1961) felt ridleys preferred to nest in the loose sand of the Chandeleur Islands rather than the compacted beaches west of the Mississippi. However, Ogren (1977) observed a small turtle, thought to be a ridley, crawling on the beach of Timbalier Island.

Inshore areas of the Gulf of Mexico appear to be important habitats for the ridley. Members of this genus are characteristically found in waters of low salinity, high turbidity, high organic content, and where shrimp are abundant (Zwinenberg 1977, Hughes 1972). Kemp's ridley in the Gulf of Mexico tends to be concentrated around major river mouths, specifically the Rio Grande and the Mississippi (Frazier 1980). Based on returns of females tagged on the nesting beach, adult ridleys move to major foraging grounds, to the south in the Campeche-Tabasco region and to the north off coastal Louisiana. Adults tagged at Rancho Nuevo were recaptured off coastal Louisiana as well as in Vermilion Bay, and animals have been reported from Vermilion Parish to Terrebonne Parish (Pritchard and Marquez 1973, Chavez 1969, Keiser 1976, Zwinenberg 1977, Dobie et al. 1961). Ridleys are commonly captured by shrimpers off the Texas coast, as well as in heavily trawled areas of the Louisiana and Alabama coast (Pritchard and Marquez 1973, Carr 1980). However, occurrence of young ridleys in shrimp trawls in coastal Louisiana has declined in the past 25 years (Hildebrand 1981). Similarly, ridleys are no longer abundant in coastal Florida (Carr and Carr 1977).

Kemp's ridley has been labeled the "Louisiana turtle" by Hildebrand (1981) and is thought to be the most abundant turtle off the Louisiana coast (Viosca 1961, Gunter 1981). The highly productive white shrimp-portunid crab beds of Louisiana from Marsh Island to the Mississippi Delta are thought to be the major feeding grounds for subadult and adult ridley (Hildebrand 1981). The current patterns in the Gulf of Mexico could aid in transport of individuals, where small turtles swimming offshore until reaching sargassum mats would enter the major clockwise loop current of the western Gulf of Mexico carrying individuals north and east along Texas, Louisiana, and subsequent coastal areas (Pritchard and Marquez 1973, Hildebrand 1981).

Although Hildebrand (1983) feels the ridley is not a resident of bays and estuaries, Keiser (1976) suggests that the ridley is the most likely sea turtle to enter Atchafalaya Bay or East Cote Blanche Bay with movements related to or controlled by salinity and food availability. Stomach analysis of specimens collected in shrimp trawls off Louisiana includes crabs (Callinectes), gastropods ((Nassarius), and clams (Nuculana, Corbula, and probably Mulinia) as well as mud balls, indicating feeding near a mud bottom in an estuarine or bay area (Dobie et al. 1961). Although considered primarily carnivorous benthic feeders (Ernst and Barbour 1972), jellyfish have also been reported as part of their diet (Fritts et al. 1983). Presence of fish such as croaker and spotted seatrout in the gut of stranded individuals in Texas may suggest that turtles feed on the by-catch of shrimp trawlers (Landry 1986). In Cedar Key, Florida, ridleys were commonly captured at the entrance to sloughs and were thought to feed on invertebrates in the shallow tidal flats and channels (Carr and Caldwell 1956). Occurrence of ridleys in coastal bays and estuaries of Louisiana would not be unexpected since many of their primary food items occur in estuarine and inshore areas with silt bottoms (National Fish and Wildlife Laboratory).

Recent information on sightings and strandings in Louisiana, based on interviews with commercial and recreational shrimpers, fishermen, divers, helicopter pilots, and offshore workers indicated that ridleys were sighted recently (since 1982) in the spring in Pass Manchac and the Rigolets (Fuller and Tappan 1986). Historical sightings, prior to 1982, included the southeastern portion of Lake Pontchartrain (Fuller and Tappan 1986).

Loggerhead Turtle (*Caretta caretta*)

The principal nesting range of the loggerhead is from Cape Lookout, North Carolina to Mexico, however the majority (90%) of the reproductive effort in the coastal United States occurs along the south-central coast of Florida (Hildebrand 1981). Nesting in the northern Gulf outside of Florida occurs primarily on the Chandeleur Islands and to a lesser extent on adjacent Ship, Horn, and Petit Bois Islands in Mississippi and Alabama (Ogren 1977). Loggerhead eggs were collected from Grand Isle, Louisiana 50 years ago (Hildebrand 1981). Ogren (1977) reported historical reproductive assemblages of sea turtles which nested seasonally on remote barrier beaches of eastern Louisiana, Mississippi, and Alabama. This included Bird, Breton, and Chandeleur Islands in Louisiana. Loss or degradation of suitable nesting habitat may be the most important factor affecting the nesting population in Louisiana today (Ogren 1977).

Loggerhead turtles are considered turtles of shallow water, less than 50 m (Rabalais and Rabalais 1980). Juvenile loggerheads are thought to utilize bays and estuaries for feeding, while adults prefer waters less than 50 m deep (Nelson 1986). During aerial surveys of the Gulf of Mexico, the majority (97%) of loggerheads were seen off the east and west coasts of Florida (Fritts 1983). Most we observed near mid-day near the surface, possibly related to surface basking behavior (Nelson 1986). Although low numbers of loggerheads were seen regularly off the coast of Louisiana and Texas, they were 50 times more abundant in Florida than in the western Gulf. The majority of the sightings were in the summer (Fritts *et al.* 1983). Loggerheads will migrate west along shallow coastal waters, as indicated by telemetry data from an individual tagged in the Mississippi Delta moving to Corpus Christi (Solt 1981).

Loggerheads are omnivorous, consuming molluscs, crabs, shrimp, sea urchins, sponges, squid, basket stars, jellyfish, and even mangrove leaves in the shallows (Caldwell *et al.* 1955, Hendrickson 1980, Nelson 1986). Presence of fish species such as croaker in stomachs of stranded individuals may indicate feeding on the by-catch of shrimp trawling (Landry 1986). They appear to be well adapted for feeding on molluscs with a heavy jaw and head (Hendrickson 1980). Caldwell *et al.* (1955) suggest that the willingness of the loggerhead to consume any type of invertebrate food permits its range to be limited only by cold water. In shallow Florida lagoons, loggerheads were found during the morning and evening, leaving the area during mid-day when temperatures reached 31°C. At dusk, turtles moved to a sleeping site and remained there

until morning, possibly in response to changes in light or water temperature (Nelson 1986).

In Texas, loggerheads were frequently observed near offshore oil platforms, natural rock reefs, and rock jetties (Rabalais and Rabalais 1980). Oyster fishermen have reported large turtles near oyster reefs in Louisiana (Deborah Fuller, pers. comm.). In Texas, large numbers of stranded individuals were observed in areas where numbers of turtles were observed offshore over hard substrates (Rabalais and Rabalais 1980).

There have been no historical (prior to 1982) or recent sightings of loggerhead turtles in Lakes Maurepas or Pontchartrain (Fuller and Tappan 1986).

Sea Turtles in the Gulf of Mexico

The majority of the general information on abundance of sea turtles in the Gulf of Mexico, and in Louisiana in particular, is based on aerial survey sightings and stranding information. Fritts et al. (1983) did not observe any ridleys in the vicinity of Marsh Island or off shore during aerial surveys. It has been suggested that aerial surveys would not provide information on turtles in nearshore Louisiana waters because low densites, behavioral patterns, or water turbidity can reduce effectiveness of aerial observations (Owens 1983, Fritts et al. 1983). Stranding and capture records do indicate that Kemp's ridley occurs in Louisiana waters. Shrimp trawling activities have been responsible for most of the captures and possibly many of the strandings (Fritts et al. 1983). Recent strandings of ridleys on Louisiana and Texas beaches may be the result of intense localized shrimping activities, although possible effects of explosives used in removal of oil rigs in the Gulf of Mexico on sea turtles are a topic of present concern (O'Byrne 1986). With loggerhead turtles in Georgia, Texas, and North Carolina, highest incidence of strandings paralleled periods of increased trawling activities in nearshore waters also (Crouse 1985, Rabalais and Rabalais 1980, Hillestad et al. 1986, Ogren 1977). Comparison of aerial survey data and stranding data in the Gulf of Mexico is limited in value for estimates of local abundance because numbers stranded reflects intensity of trawling rather than actual abundance (Fritts et al. 1983). In addition, differences in sampling effort and presence of longshore and nearshore currents may account for localized differences in strandings (Hillestad et al. 1978). In Louisiana, the coastal areas are less accessible and probably less utilized by humans so that stranded animals may go unnoticed (Fritts et al. 1983). Efforts to increase information on strandings in Louisiana have intensified and several individuals now routinely patrol several areas of the Louisiana coastline and supply any information found to the Sea Turtle Stranding Network (STSN) (S. Rabalais, pers. comm.).

It has been suggested that ridleys and loggerheads may burrow in estuarine mud along the gulf coast during the winter when water temperatures are too low for normal activity, and remain buried in the mud until warmer weather. Observations of turtle fishermen at Cedar

Key, Florida, noted their absence in winter and reappearance in the spring covered with mud (Pritchard and Marquez 1973), although not all turtles are mudcovered suggesting that not all individuals are buried in the mud (Carr et al. 1980). The winter capture of torpid loggerheads and fewer ridleys in the Port Canaveral Ship Channel off eastern Florida (Joyce 1981), as well as torpid individuals by Carr et al. (1980) strongly suggests that the animals may be hibernating in the soft bottom sediments and walls of the ship channel. There is no information on whether or not turtles do bury themselves in the coastal bays or lakes of Louisiana.

Impact of Shell Dredging on Sea Turtles

During the warm months of the year when ridleys and loggerheads are active, it is not expected that shell dredging will have any direct impact on any turtles should they occur in the area. The relatively slow progress of a dredge in an area, along with associated noise and water disturbance forewarns such motile creatures which would then be expected to escape capture.

There is no evidence of hibernation of sea turtles in Louisiana, however any turtle occurring in Lakes Maurepas and Pontchartrain would likely only be affected by dredging operations during the cooler months when turtles might be buried in the silty sediments. If torpid, similar to the situation in Florida, they would be unable to escape either destruction or capture by the hydraulic suction.

No turtles have been seen during shell dredging operations in this area (D. Palmore, pers. comm.). If any individuals have been entrained in the past, they may or may not have been observed depending on the vigilance of an observer and/or the nature of the turtle fragments, if any, transported onto the dredge.

Occurrence of ridleys or loggerheads in the bottom sediments of any previously dredged areas is unknown. The possibility exists that the dredged sediments re-deposited in an area following passage of a shell dredge as well as altered bottom configuration may be attractive to turtles for hibernation and could draw animals to an otherwise less attractive area. However, little information exists on the actual frequency of occurrence of sea turtles burying in the sediments in the Gulf of Mexico in general. Although several theories exist as to why the Canaveral Ship Channel off Florida harbors large concentrations of loggerheads, no information is available on what features are suitable for hibernation.

Methods to Reduce Impact of Shell Dredging on Sea Turtles

If it were determined that Kemp's ridleys or loggerheads were indeed hibernating in the areas to be dredged, methods available to protect turtles are somewhat limited. Attempts could be made to physically remove turtles from an area in a manner similar to that used in Florida where the area to be dredged was trawled prior to dredging and captured individuals were released away from the area. Such release may be

ineffective, however, if water temperatures are low enough to produce torpor, they are too low to permit turtles to re-bury themselves.

Certain types of draghead dredges, which function by hydraulic erosion, can be modified with cages or deflector systems to prevent turtle entrainment (Joyce 1982). Present use of the California type draghead has significantly reduced the capture of loggerhead turtles in Florida. This modification was the result of findings of an interagency task force formed to investigate methods for reducing the incidental injuring and/or killing of endangered and threatened turtles in connection with hopper dredging in federal navigation channels (Joyce 1981) (Sea Turtle/Dredging Task Force). In addition to the modified draghead, the overflow is monitored using large mesh baskets designed to retain any turtles or turtle fragments (P. Schmidt, pers. comm.). Owing to the nature of the material being dredged in Louisiana, installation of such a collection basket on a shell dredge would probably not provide any additional information on the presence of sea turtles. Replacement of the "fish-mouth" suction dredge head with another type of dredge head could be feasible if entrainment of turtles were ever found to be a problem.

Aside from physical modification of the existing dredge equipment, dredging only during non-threatening times of the year is another alternative to reduce impact on sea turtles. If turtles are hibernating in the area, the period of hibernation would be when they are most vulnerable. Prohibiting dredging in these areas during times of the year when water temperatures are less than 15°C (Mrosovsky 1980), could eliminate any encounters with animals that would be hibernating under these temperature regimes. The time of year when water temperatures in Lakes Maurepas and Pontchartrain would be expected to be less than 15°C occurs from December to February.

Conclusions

1. Kemp's ridley turtle may occur in Lakes Pontchartrain and Maurepas, based on historical and recent sighting information. No loggerhead turtles have been sighted in the lakes.

2. No sea turtles have been observed during any past shell dredging operations in this region.

3. Sea turtles would be expected to avoid the slow-moving dredge during the majority of the year (March through November).

4. There is no evidence of hibernation of sea turtles in Lakes Pontchartrain and Maurepas.

5. Hibernating sea turtles, if present, would occur when water temperatures were 15°C or less, generally during the period from December through February in coastal Louisiana. Hibernating individuals may be subject to damage or destruction by sweeper-type dredge.

6. Based on present information, the impact of shell dredging on Kemp's ridley in Lakes Pontchartrain and Maurepas is thought to be negligible.

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Planning Division
Environmental Analysis Branch

June 17, 1986

Mr. Dennis B. Jordan
Field Supervisor
U. S. Fish and Wildlife Service
Jackson Mall Office Center
300 Woodrow Wilson Avenue, Suite 3185
Jackson, Mississippi 39213

Dear Mr. Jordan:

We are requesting information concerning listed and proposed threatened and/or endangered species which may be impacted by extension of Section 10 and Section 404 permits to dredge clam shells (Rangia) in the Lakes Area (LA) - Lakes Maurepas and Pontchartrain. The LA is shown in Figure 1. The shaded areas indicate where shell dredging is restricted. Although Lake Maurepas is currently closed to shell dredging, it is possible that it could be reopened in the future.

Clam shells are dredged by pushing a rotary cutter through bottom sediments to loosen the material which is then collected by hydraulic suction and pumped aboard the dredge. The shells are extracted from the sediment by washing and the sediments are discharged overboard back into the water. Once a deposit of shells is located, the dredge circles and continues to dredge the area until the rate of shell recovery falls below economic feasibility. The bottom configuration immediately after dredging is a trench about 2 to 3 feet deep and 4 to 5 feet wide.

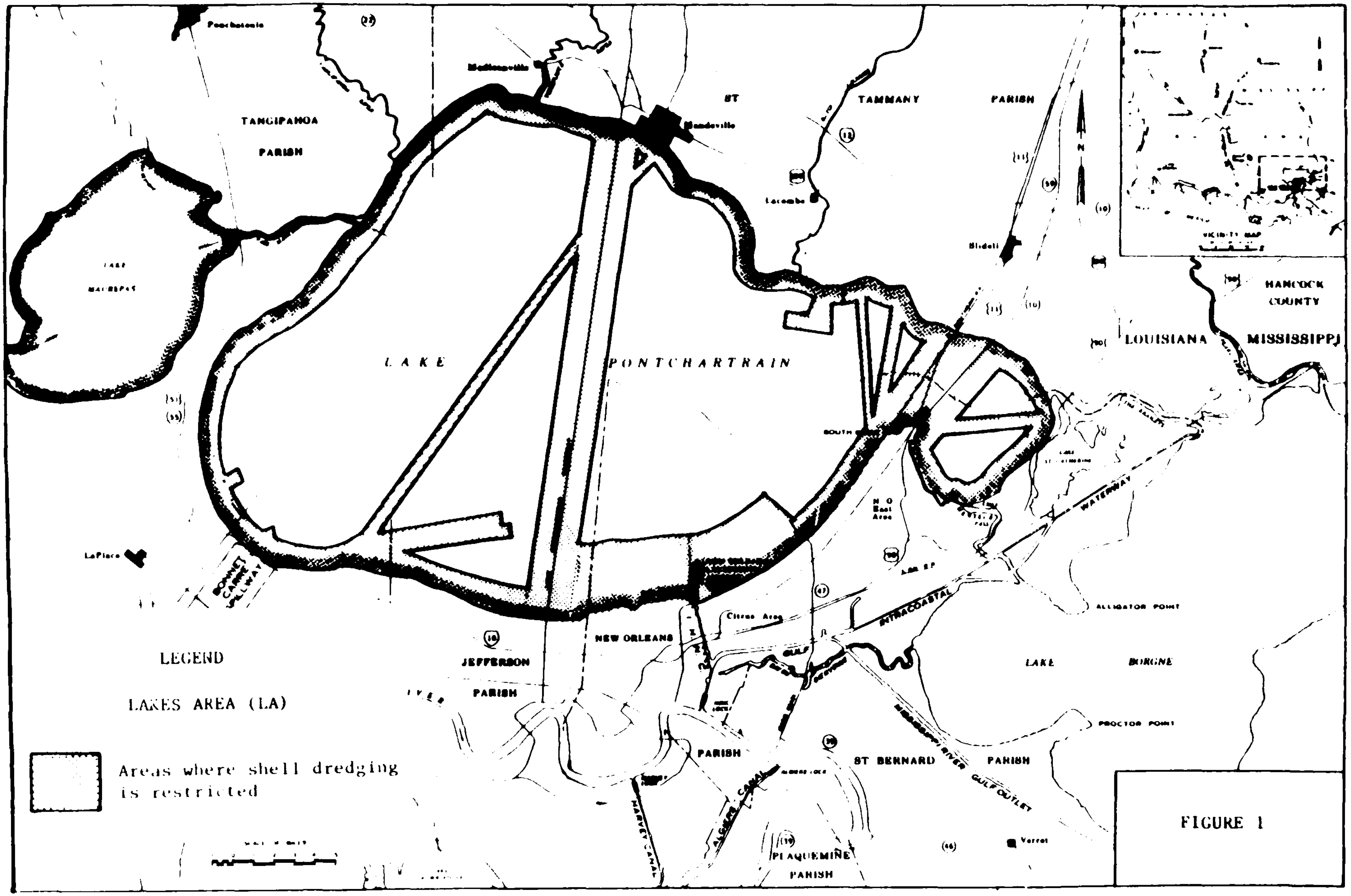
The harvested clam shells are used in the manufacture of cement, glass, chemicals, pharmaceuticals, chicken and cattle feed, and agricultural lime. They are also used for road construction, water purification systems, and oyster cultch material.

If you have any questions concerning this matter, please contact Mr. Dennis Chew, telephone (504) 862-2523.

Sincerely,

Cletis R. Wagahoff
Chief, Planning Division

Enclosure



Ponchatoula
Madisonville
TANGIPAHOA
PARISH
ST
TAMMANY
PARISH
Mandeville
Lacombe
Slidell
LAKE
PONTCHARTRAIN
LaPlace
BONNET CARRE SPILLWAY
HANCOCK
COUNTY
LOUISIANA
MISSISSIPPI
NEW ORLEANS
JEFFERSON
PARISH
Citrus Area
INTRACOASTAL
WATERWAY
ALLIGATOR POINT
LAKE
BORGNE
PROCTOR POINT
ST BERNARD
PARISH
MISSISSIPPI RIVER GULF OUTLET
HARVEY CANAL
ALGIERS CANAL
PLAQUEMINE
PARISH
Verret
LEGEND
LAKES AREA (LA)
Areas where shell dredging is restricted

FIGURE 1

Planning Division
Environmental Analysis Branch

June 17, 1986

Mr. Charles A. Oravetz
Protected Species Management Branch
National Marine Fisheries Service
Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, Florida 33702

Dear Mr. Oravetz:

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Sincerely,

Cletis R. Wagahoff
Chief, Planning Division

Enclosure

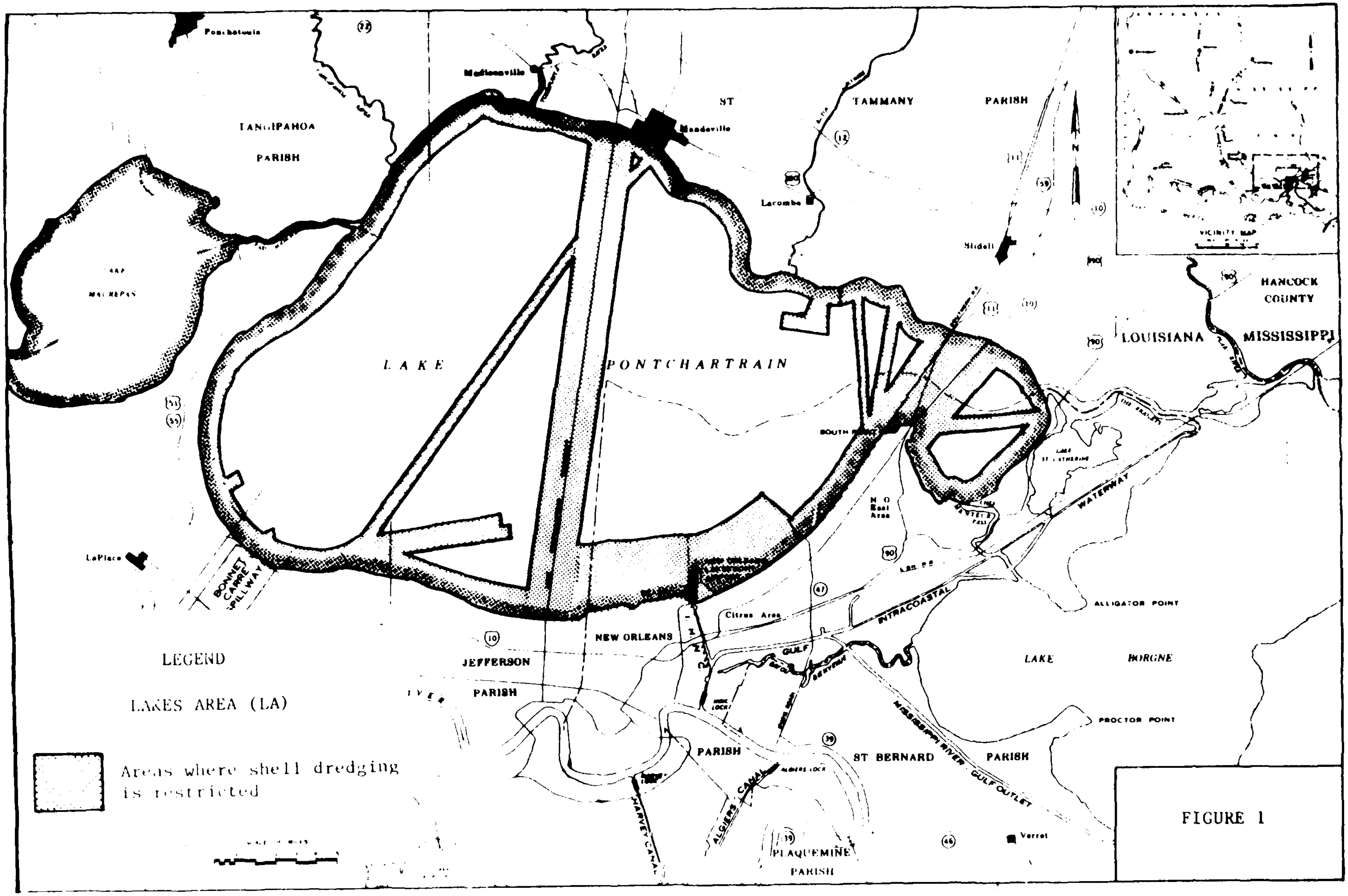
Ponchatoula
Madisonville
Mandeville
ST
TAMMANY
PARISH
TANGIPAHOA
PARISH
Lacombe
Slidell
HANCOCK
COUNTY
LOUISIANA
MISSISSIPPI
LAKE
PONTCHARTRAIN
N O
East
Area
LaPlace
BONNET
CARRE
SPILLWAY
NEW ORLEANS
JEFFERSON
PARISH
Citrus Area
INTRACOASTAL
WATERWAY
GULF
ALLIGATOR POINT
LAKE
BORGNE
PROCTOR POINT
ST BERNARD
PARISH
PARISH
MISSISSIPPI RIVER GULF OUTLET
Verret
PLAQUEMINE
PARISH
HARVEY CANAL
ALGIERS CANAL
VICINITY MAP
LEGEND
LAKES AREA (LA)
Areas where shell dredging
is restricted

FIGURE 1

United States Department of the Interior

FISH AND WILDLIFE SERVICE

JACKSON MALL OFFICE CENTER
300 WOODROW WILSON AVENUE, SUITE 316
JACKSON, MISSISSIPPI 39213

June 30, 1986

IN REPLY REFER TO:
Log No. 4-3-86-541

Mr. Cletis R. Wagahoff
U.S. Army Corps of Engineers
Post Office Box 60267
New Orleans, LA 70160-0267

Dear Mr. Wagahoff:

This responds to your letter of June 17, 1986, concerning Section 10/404 permits to dredge clam shells in Lakes Pontchartrain and Maurepas, Louisiana. We have reviewed the information you enclosed relative to the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.).

Our records indicate no endangered, threatened or proposed species, or their critical habitat occurring in the project area. Therefore, no further endangered species consultation will be required for this project, as currently described.

If you anticipate any changes in the scope or location of this project, please contact Mike Dawson of our office, telephone 601/965-4900, for further coordination.

We appreciate your participation in the efforts to enhance the existence of endangered species.

Sincerely yours,

Dennis B. Jordan

Dennis B. Jordan
Field Supervisor
Endangered Species Field Office

cc:
Department of Wildlife & Fisheries, New Orleans, LA
ES, FWS, Lafayette, LA

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, FL 33702

July 8, 1986 F/SER23:PWR:dcp

Mr. Cletis R. Wagahoff
Chief, Planning Division
New Orleans District, COE
P. O. Box 60267
New Orleans, Louisiana 70160-0267

Dear Mr. Wagahoff:

This responds to your June 17, 1986, letter regarding information on listed threatened/endangered species which may be impacted by proposed clam dredging activities in Lakes Maurepas and Pontchartrain, Louisiana. The attached list provides the threatened and endangered species under National Marine Fisheries Service jurisdiction that may be present in the project area.

For a major federal action, the agency must conduct a biological assessment to identify any endangered or threatened species which may be affected by such action. The biological assessment must be complete within 180 days after receipt of the species list, unless it is mutually agreed to extend this period. The components of a biological assessment are also attached.

At the conclusion of the biological assessment, the Federal agency should prepare a report documenting the results. If the biological assessment reveals that the proposed project may affect listed species, the formal consultation process shall be initiated by writing to the Regional Director at the address on the letterhead. If no effect is evident, there is no need for formal consultation. We would however, appreciate the opportunity to review your biological assessment.

If you have any questions, please contact Paul Raymond, Fishery Biologist, FTS 826-3366.

Sincerely yours,

Paul W. Raymond
for

Charles A. Oravetz, Chief
Protected Species Management Branch

Enclosures

cc: F/M412
F/SER11

Endangered and Threatened Species and Critical Habitats Under NMFS Jurisdiction

Louisiana Bays

LISTED SPECIES	SCIENTIFIC NAME	STATUS	DATE LISTED
Kemp's (Atlantic) ridley sea turtle	*Lepidochelys kempi*	E	12/02/70
loggerhead sea turtle	*Caretta caretta*	Th	7/28/78

SPECIES PROPOSED FOR LISTING
None

CRITICAL HABITAT
None

CRITICAL HABITAT PROPOSED FOR LISTING
None

Guidelines for Conducting a Biological Assessment

(1) Conduct a scientifically sound on-site inspection of the area affected by the action. Unless otherwise directed by the Service, include a detailed survey of the area to determine if listed or proposed species are present or occur seasonally and whether suitable habitat exists within the area for either expanding the existing population or reintroducing a new population.

(2) Interview recognized experts on the species listed, including those within the Fish and Wildlife Service, the National Marine Fisheries Service, state conservation agencies, universities and others who may have data not yet found in scientific literature.

(3) Review literature and other scientific data to determine the species distribution, habitat needs, and other biological requirements.

(4) Review and analyze the effects of the action on the species, in terms of individuals and population, including consideration of the cumulative effects of the action on the species and habitat.

(5) Analyze alternative actions that may provide conservation measures.

(6) Conduct any studies necessary to fulfill the requirements of (1) through (5) above.

(7) Review any other information.

Planning Division
Environmental Analysis Branch

December 1,1986

Mr. Charles A. Oravetz
Protected Species Management Branch
National Marine Fisheries Service
Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, Florida 33702

Dear Mr. Oravetz:

In accordance with the Endangered Species Act of 1973, a biological assessment which addresses the potential impacts of [redacted] shell dredging on Kemp's ridley and loggerhead turtles in Louisiana is submitted.

Based on this biological assessment, the U.S. Army Corps of Engineers, New Orleans District, has determined that the project, as proposed, would have no adverse impact on the subject species in Lake Maurepas and Lake Pontchartrain.

It is our opinion, based on these considerations, that initiation of consultation is not necessary at this time. If you have any questions on the assessment, please feel free to contact Ms. Diane S. Ashton of this office, telephone (504) 862-1735.

Sincerely,

Cletis R. Wagahoff
Chief, Planning Division

Enclosure

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, FL 33702

December 25, 1986 F/SER23:PWR:dcp

Mr. Cletis R. Wagahoff
Chief, Planning Division
New Orleans District, COE
P. O. Box 60267
New Orleans, LA 70160-0267

Dear Mr. Wagahoff:

This responds to your December 1, 1986, letter regarding the proposed clam shell dredging activities in Lake Maurepas and Lake Pontchartrain, Louisiana. A biological assessment (BA) was transmitted pursuant to Section 7 of the Endangered Species Act of 1973 (ESA).

We have reviewed the BA and concur with your determination that populations of endangered/threatened species under our purview would not be affected by the proposed action.

This concludes consultation responsibilities under Section 7 of the ESA. However, consultation should be reinitiated if new information reveals impacts of the identified activity that may affect listed species or their critical habitat, a new species is listed, the identified activity is subsequently modified or critical habitat determined that may be affected by the proposed activity. If you have any new information or questions concerning this consultation, please contact Mr. Paul Raymond, Fishery Biologist, at FTS 826-3366.

Sincerely yours,

Charles A. Oravetz

Charles A. Oravetz, Chief
Protected Species Management Branch

cc: F/M412
F/SER11

APPENDIX B

REGULATIONS, RESTRICTIONS, AND LEASE AGREEMENT FOR SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS

TABLE OF CONTENTS

APPENDIX B

REGULATIONS, RESTRICTIONS, AND LEASE AGREEMENT FOR SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS

Introduction

The dredging companies that harvest clam shells from the lakes area operate under a lease agreement from the Louisiana Department of Wildlife and Fisheries as well as numerous regulations and restrictions imposed by several state and Federal agencies. This appendix provides lists of the regulations and restrictions and a copy of the lease agreement.

LAKE PONTCHARTRAIN SHELL DREDGING REGULATIONS

All operations will be conducted in compliance with U.S. Army Corps of Engineers (USACE), Environmental Protection Agency, U.S. Coast Guard, Louisiana Department of Environmental Quality, Louisiana Department of Wildlife and Fisheries (LDWF), Louisiana Department of Natural Resources, (DNR) rules, regulations, and restrictions. (USACE)

Monitoring System

1. Permittee shall at its expense install a Loran C continuous location recording system (accurate to 100 feet) or a similar device acceptable to the Department of Wildlife and Fisheries and the Department of Natural Resources on each operating shell dredge within six (6) months of the effective date of the permit. The system shall be certified tamper proof by the manufacturer and accessible to the Coastal Management Section (CMS), Department of Louisiana Wildlife and Fisheries (LDWF) or their designees. Permittee shall notify CMS/DNR within one working day after a malfunction of the system. Each dredge shall remain within 1,000 feet of its position at the time the malfunction occurs until CMS and LDWF have been contacted. (DNR)

> "Should a malfunction occur during non-working hours, permittee shall make reasonable efforts to notify CMS personnel at telephone numbers to be supplied to permittee. If after reasonable efforts, permittee is unable to notify CMS, dredges may continue to operate but CMS shall be notified as soon as possible and in no event more than one working day after the malfunction occurs. Dredging operations may continue during these periods, but permittee shall insure that no restricted zones are entered." (DNR)

2. Records of each dredge's location recorded by the system shall be delivered to LDWF and shall be available for inspection by representatives of CMS or the public. (DNR)

3. Each operating dredge shall be required to have a device, as specified by the Department of Wildlife and Fisheries, installed on board which will plot, map, and record all movements and locations of the dredge vessels. This device shall be tamper proof and installation is mandatory. (LDWF)*

4. A copy of the weekly reports submitted to LDWF shall also be submitted to CMS. Weekly reports to CMS shall include records of the dredge location during every six (6) hour period, and the location of any exposed reefs or pipelines and gathering lines associated with mineral production encountered. (10/2/84, DNR)

5. Lessee shall report on a calendar weekly basis, on a form provided by the Department, the precise location(s) of the dredging activity and any other information required by the Department. A calendar week shall be

defined as Sunday through Saturday. These report forms shall be submitted to the Department or postmarked addressed to the Department on the Monday following the end of the calendar week. (LDWF)*

6. Lessee shall permit routine field inspections by department personnel on a periodic basis for the purposes of verifying the locations of dredges, verifying the quantity of shell aboard, and monitoring compliance with the lease and regulations. For the purpose of this inspection the lessee shall allow the Department of Wildlife and Fisheries personnel to board vessels and inspect documents and records pertinent to the lease and regulations, inspect positioning equipment and recording equipment for accuracy and inspect shell cargo and inspect any other operations of the dredge. (LDWF)*

7. Each operating dredge shall be required to have on board at all times a person with the authority to stop and/or move the dredge or other equipment upon notification by the designated representative(s) of the Department. (LDWF)*

Permit Violations

Permittee shall be subject to the following actions under LA R.S. 48:213.17 for the violation of any condition of this permit (DNR):

1. The issuance of cease and desist orders;

2. The suspension, revocation, or modification of this permit;

3. The institution of judicial action for an injunction, declaratory relieve, or other remedy as may be necessary to insure against activities not in conference with law, regulations, or this permit;

4. The imposition of civil liability and assessment of damages;

5. The issuance of orders where feasible and practical for the payment of restoration cost or for actual restoration of areas disturbed;

6. The imposition of other reasonable and proper sanctions for uses conducted within the coastal zone not in accordance with law, regulations or this permit;

7. The imposition of cost and reasonable attorneys fees where appropriate; and

8. The imposition of a fine of not less than $100 and not more than $500, orimprisonment for not more than 90 days, or both, in instances where permittee is found to have knowingly and intentionally violated the law, rules and regulations, or any conditions of this permit.

Operating Time, Number and Specifications of Dredges (10/2/84, DNR)

1. A total of no more than seven (7) shell dredges shall operate in Lake Pontchartrain at any time.

2. The permittee shall not operate more than _______ dredges named _____ _______ and ________________ within the area covered by the permit, whose specifications, as certified by permittee, are as follows:

DREDGE NAME:
COAST GUARD REGISTRY:
CURRENT OWNER:
CURRENT OPERATOR:
PUMP MFG.:
PUMP SIZE:
PUMP CAPACITY:
WASHWATER PUMP MFG. CO.:
WASHWATER PUMP TYPE:
TOTAL DISCHARGE:
SOLID RECOVERY:
SCOOP WIDTH:

3. Permittee shall make no alteration to either dredge which would result in an increase in the pump capacities, total discharge, or recovery rates of that dredge from the specifications set forth in this condition.

4. The Secretary of the Department of Natural Resources reserves the right to subsequently modify, including the right to reduce the number of dredges, modify the dredges' production capacities, and/or modify the operation or discharge processes of the dredges in accordance with the provisions of this permit or La. R.S. 49:213.1 et seq. and the regulations adopted thereunder. The Secretary may require the submission of additional data prior to taking action under this condition and may require good cause to be shown if dredging operations are sought to be increased above their currently permitted levels.

Dredge Discharge

The dredge discharge shall be directed over the dredged cut. After an area has been dredged, it shall be surveyed and level so as not to cause navigation hazards. (DNR)

OTHER DREDGE SPECIFICATIONS

1. Distance between any two operating dredges shall not be less than 300 yards. (5/25/82, LDWF)

2. Each operating dredge in Lakes Pontchartrain and Maurepas shall display the dredge name in 12 inch high letters, width proportional and contrasting color, in such a manner as to be readily identifiable from the air. (LDWF)

3. A zone of operations schedule shall be determined prior to January 1 of each year and this information shall be disseminated to the fishing community. Determination of zones and schedule shall be by the Department of Wildlife and Fisheries in coordination with the shell dredging industry. (LDWF)

Offsite Restoration (DNR)
As compensation for disturbance of the water bottom during dredging, the permittee shall at its expense undertake offsite restoration when recommended by the Secretary of the Louisiana Department of Wildlife and Fisheries for improvement of the marine environment. Such offsite restoration shall not exceed one (1) acre of shell reef 1 foot thick for every 200,000 cubic yards dredged from the permitted area. These restoration reefs shall be no less than one (1) acre in size and shall be located in areas recommended by LDWF and CMS and which are restricted from shell dredging.

Ecological Impacts Study of Rangia Shell Dredging in Lakes Pontchartrain and Maurepas (DNR)

1. Permittee shall be required to cooperate in any studies of the ecological impacts of *Rangia* shell dredging in Lakes Pontchartrain and Maurepas which are undertaken by CMS/DNR and/or LDWF and/or any Advisory Council-Special Management Area (Lake Pontchartrain) which may be by the Secretary of the Department of Natural Resources. In connection with such study, the permittee shall be required to furnish any and all data within its custody or control which pertains to the ecological impacts of shell dredging.

2. This study may include an investigation of long-term variations in water quality and the benthic community which may be caused by shell dredging and may involve a sampling regimen.

3. Dredging operations shall not damage the oyster beds, *Mercenaria* clam beds or bottoms owned by the state where these operations damage or prove harmful to fish, oysters, aquatic or other wildlife resources in said beds or waterbottoms. (LDWF)

Archeological Restrictions

If any archeological or historical materials (i.e., pottery, bone, timbers, ship fittings, etc.) are encountered, the locations of these finds will be mapped and the State Historic Preservation Officer (SHPO) will be immediately notified. Dredging will be discontinued in that area until SHPO approval is given to resume dredging activities. (USACE)

Duration of Permit

This permit shall be valid for five years from December 30, 1982 in the present form unless sooner revoked or modified for good cause shown (other than permit violations) after thirty (30) days written notice to permittee and opportunity for permittee to be heard on the alleged basis for revocation or modifications. Additionally, on the second and fourth anniversary of the original permit date, a mandatory administrative conference and public hearing will be held by the Secretary of the Department of Natural Resources in one or more of the parishes adjoining Lake Pontchartrain and Lake Maurepas to assess the environmental impact of permit activities to the lakes. Permittee may be required to produce at such conference all books, records, documents or data in its custody which may be of propative value in assessing the environmental impact of the activities of this permit. Good cause may include but shall not be limited to additional scientific data resulting from studies by the Department of Natural Resources, the Department of Wildlife and Fisheries, or other qualified individuals or entities. (6/6/83, DNR)

Additional Conditions

1. The applicant will notify the Coastal Management Section of the date on which approved work began on site using the appropriate green commencement card. (DNR)

2. The applicant shall insure that all sanitary sewage and/or related domestic wastes generated during the subject project activity and at the site, thereafter, as may become necessary shall receive the equivalent of secondary treatment with disinfection prior to discharge into any of the streams or by the State Sanitary Code. Such opinion as may be served by those comments offered herein shall not be construed to suffice as any more formal approval(s) which may be required of possible sanitary details (i.e. provisions) scheduled to be associated with the subject activity. Such shall generally require that appropriate plans and specifications be submitted to DHHR for purposes of review and approval prior to any utilization of such provisions. (DNR)

3. Failure to comply with any of these regulations and/or stipulations in the lease agreements shall be considered to be in violation and the lessee shall be subject to immediate suspension of dredging activities by the Secretary or his designee. (LDWF)

* Regulations to be adopted by Wildlife and Fisheries Commission (Pending Approval)

LAKE PONTCHARTRAIN SHELL DREDGING RESTRICTIONS

All operations will be conducted in compliance with U.S. Army Corps of Engineers (USACE), Environmental Protection Agency, U.S. Coast Guard, Louisiana Department of Environmental Quality (DEQ), Louisiana Department of Wildlife and Fisheries (LDWF), and Louisiana Department of Natural Resources (DNR) rules, regulations, and restrictions. (USACE)

Dredging may not be conducted in the following areas or at the following locations:

1. Within one (1) mile of the shorelines of Lakes Maurepas and Pontchartrain. (USACE, DNR, LDWF)

2. Within three (3) miles of the southern shoreline of Lake Pontchartrain between the Lake Pontchartrain Causeway in Jefferson Parish and Paris Road in Orleans Parish. (USACE, DNR)

3. Within 3 miles of the shoreline in that portion of Orleans Parish between the Jefferson Parish line and Paris Road. (LDWF)

4. Within one (1) mile of the Lake Pontchartrain Causeway. (USACE, DNR, LDWF)

5. Within one-half (0.5) mile of the Southern Railway trestle, Interstate Highway 10 twin bridges, and U.S. Highway 11 bridge in the eastern part of Lake Pontchartrain. (USACE, DNR)

6. In an area bounded by lines parallel to and 1/2 mile westerly from the Southern Railway trestle and 1/2 mile easterly from the eastern edge of the Interstate Highway 10 twin bridges. (LDWF)

7. Near pipelines as follows (LDWF):

   a. Within 1/4 mile of the east-west Southern Natural Gas Company pipeline in the portion of the lake east of Interstate Highway 10.
   b. Within 1/4 mile of the marked Southern Natural Gas Company pipeline corridor extending from the vicinity of South Point to a location near the mouth of Bayou Lacombe.
   c. Within 1/4 mile of the pipeline which extends from the north shore about 1 mile southeast of the mouth of Bayou Lacombe.
   d. Within 1/4 mile of the Collins Pipeline Company pipeline in the eastern portion of the lake.
   e. Within 1/4 mile of the marked United Gas Pipeline Company corridor in the central portion of the lake.

8. Within one-quarter (0.25) mile of the Southern Natural, United Gas, and Collins pipelines and/or marked pipeline corridors in Lake Pontchartrain. (USACE)

9. Within one-fourth (0.25) mile of the pipelines located in the following State of Louisiana pipeline rights-of-way (DNR):

a. R/W #1875 - Southern Natural Gas

b. R/W #1142 - Tennessee Gas

c. R/W #1884 - Transcontinental Gas Pipeline Corp.

d. R/W #1080 - Southern Natural Gas

e. R/W #1930 - Acadian Gas Pipeline System

f. R/W #2156 - Grigsby Petroleum

g. R/W #1297 - United Gas Pipeline

h. R/W #2032 - Louisiana Intrastate Gas

i. Unnumbered R/W's:

1. United Gas - dated July 11, 1941

2. United Gas - dated July 7, 1958

3. Shell Oil - dated February 19, 1958

4. Humble Oil - dated January 13, 1960

Said areas and pipelines are outlined on the "blue-line" copy of the National Oceanic and Atmospheric Administrations Nautical Chart No. 11369 (Lakes Pontchartrain and Maurepas), 33rd Ed., Oct. 23/83, marked "Exhibit A". Thedescriptions in the Rights-of-Way instruments shall control over the delineations in the Exhibit.

10. Under any aerial powerline. (USACE)

11. Under the Louisiana Power and Light Company aerial transmission lines in the western portion of the lake. (LDWF)

12. Within 1,000 feet of an operating oil or gas well drilling rig. (USACE, DNR)

13. Within 500 feet of an active oil or gas well platform or production facilities platform. (USACE, DNR)

14. In areas in the eastern part of Lake Pontchartrain containing live oysters. (USACE)

15. Within Lake Maurepas until a monitoring system program approved by the New Orleans District is implemented to detect the onset of potentially unacceptable situations relative to turbidity. Such a program would be used to determine when dredging will be temporarily suspended until more favorable conditions arise. (USACE)

LEASE

STATE OF LOUISIANA

PARISH OF ORLEANS

This Agreement made by, between and among the LOUISIANA DEPARTMENT OF WILDLIFE AND FISHERIES, a creature of the State of Louisiana, herein acting through Jesse J. Guidry, its Secretary (party of the First Part); and LOUISIANA MATERIALS COMPANY, INC., and PONTCHARTRAIN MATERIALS, a Louisiana Joint Venture, represented by Pontchartrain Materials Corporation, corporations duly organized and existing under the laws of the State of Louisiana, and each represented herein by its President, and RADCLIFF MATERIALS, INC., an Alabama corporation qualified to do business in Louisiana herein represented by its President (parties of the Second Part).

The Louisiana Department of Wildlife and Fisheries may hereinafter be referred to as DEPARTMENT; and LOUISIANA MATERIALS COMPANY, INC., PONTCHARTRAIN MATERIALS CORPORATION, and RADCLIFF MATERIALS, INC., may hereinafter jointly be referred to as LESSEES and may hereinafter individually be referred to as LESSEE.

Subject to the reservations, terms, royalties and conditions hereinafter cited, the Department sells and grants to the LESSEES, its successors or assigns, the exclusive right and privilege of taking and removing shells, shell deposits of all varieties from any and all of the water bottoms and beds of Lake Pontchartrain and Maurepas in the State of Louisiana, and LESSEES agree among themselves, the terms, reservations and conditions being as follows:

1.

The rights, privileges and obligations granted herein are joint and several for all Purchasers except to the extent herein set forth. The joint and several rights and privileges herein granted shall be for a period of fifteen (15) years beginning May 18, 1982, and ending May 17, 1997, and shall be subject to all existing oil and gas pipeline rights-of-way, mineral leases and servitudes granted by third parties and the State of Louisiana through the Department of Natural Resources located in the area hereinabove described and of record as of the date of this Agreement.

2.

The term of this Agreement may be extended at the option of the LESSEES who have not lost or forfeited their rights hereunder for two (2)

successive periods of five (5) years each conditioned upon the LESSEES giving to the Department and the Louisiana Wildlife and Fisheries Commission written notice of its intention to exercise such extension option at least one (1) year prior to the expiration date of the term then in effect and such written notice having been given by the LESSEES to the Department, this Agreement shall be extended without further formality.

3.

As consideration under this Agreement, the LESSEES, subject to the adjustment set forth in the last paragraph of this item 3, shall pay the Department the following royalties;

(a) During the period May 18, 1982, through and including December 31, 1982, the LESSEES shall pay the Department a royalty of thirty and one-half cents (30.5¢) per cubic yard for all shell and/or other shell deposits removed by the LESSEES from the above described water bottoms.

(b) Beginning on January 1, 1983, and on the first day of January in each year thereafter during the balance of this Agreement, the LESSEES shall pay the Department a royalty for each such calendar year which shall be increased or decreased from the previous year's per cubic yard royalty provided for in (a) above, based on the following formula:

Said royalty of thirty and one-half cents (30.5¢) per cubic yard shall be adjusted on the first day of January of each year for the ensuing twelve month period by multiplying said thirty and one-half cents (30.5¢) per cubic yard royalty by the quotient in which the numerator shall be the All Urban Consumer Price Index, or its successor Index, calculated by the appropriate agency of the Federal Government and publicized by the Federal Reserve Bank of St. Louis, Missouri (hereinafter called the ALL URBAN CONSUMER PRICE INDEX), for the month of December immediately preceding the twelve month period for which said royalty is being adjusted, and the denominator shall be the All Urban Consumer Price Index for the month of April 1982. The resulting quotient expressed in a percentage shall be applied to the thirty and one-half cents (30.5¢) base royalty and shall be the basis for the new royalty. An example of the calculation is attached hereto as Exhibit A. In the event the All Urban Consumer Price Index has not been published in time to compute any monthly payment due the Department by LESSEES, then LESSEES shall pay the Department the same royalty paid during the preceding month or months and as soon as the determining monthly All Urban Consumer Price Index is published, LESSEES shall make such adjustments to the previous royalty payments as may be necessary to correctly pay the Department the adjusted royalties due hereunder.

The foregoing notwithstanding, in no event shall the royalty payable by LESSEES to the Department throughout the period of this Contract be less than thirty and one-half cents (30.5¢) per cubic yard.

Notwithstanding anything herein to the contrary, the Department shall have the right, at the end of each five year period of this lease, to review the base royalty of thirty and one-half cents (30.5¢) and, if the real value of the resources has increased or decreased to an extent not covered by the inflation provision of this contract and all economic and competitive conditions prevalent at the time, then to increase or decrease the base royalty by an amount as may be determined by the Department but in no event shall such increase exceed 25%.

4.

It is expressly understood and agreed that in the event of any increase by the Legislature of the State of Louisiana in the prevailing royalty rates for the removal of shell or shell deposits from any of the water bottoms of this state, the LESSEES shall pay as consideration under this Agreement any increased royalty per cubic yard so provided for by action of the Louisiana Legislature for shell and/or shell deposits thereafter taken by the LESSEES.

5.

It is understood that payment of royalties for all shells and/or shell deposits removed by the LESSEES during any one calendar month shall be made on or before the 15th day of the succeeding month, all in a manner consistent with the applicable law of the State of Louisiana.

6.

Each LESSEE warrants that each LESSEE has currently under such LESSEE'S exclusive ownership and/or control an adequate supply of dredges, adequately powered tow boats for the operating conditions, barges, cranes, machinery, tools and implements of every kind or character which may be necessary to the taking and removal of shell and/or shell deposits under the terms of this Agreement. It is expressly understood that the Department shall incur no liability or expense of any kind in connection with the ownership, control and operation of such equipment by each such LESSEE, including but not limited to all claims, actions or causes of action by all third parties, each such LESSEE, its employees, agents, officers, directors, successors and assigns, their employees, agents, officers and directors caused by each such LESSEE, its employees,agents, successors and assigns in the exercise of the dredging rights and privileges granted by this Agreement.

7.

Each LESSEE agrees that such LESSEE shall be liable and responsible only for damage or damages, whether to the property of the State or of any individual, firm or corporation, or to any person or persons, caused by the negligence or breach of contract of such LESSEE or by such LESSEE'S agents, directors, or employees of any kind, and none of the LESSEES shall be responsible for damage caused by any of the other LESSEES, their agents, directors, or employees. Each LESSEE, its successors and assigns agree to indemnify the Department for all such damage or damages and to hold the Department harmless from all such damage or damages caused by such LESSEE, including assuming the cost and expense of defending all claims, actions, or causes of action which are or may be filed seeking such damage or damages. Each LESSEE shall specifically obtain insurance coverage of this indemnity provision and shall furnish the Department with satisfactory evidence of such coverage of not less than three million dollars.

8.

At the Department's request, each LESSEE shall notify the Department in writing, at least ten (10) days prior to putting into actual service any dredge, barge or tow boat used in the removal of shells and/or shell deposits, together with the capacity of each, and the Department may thereupon verify the measurements of said barges. In case the giving of such notice by the LESSEES becomes impractical, then the LESSEES shall give written notice within ten (10) days after such vessel is placed in service.

9.

Each LESSEE binds and obligates itself not to dredge within three hundred (300) yards of the dredging operations of any of the other LESSEES hereunder or any Sublessees hereunder.

10.

Each LESSEE, on or before the 15th day of each month, shall furnish the Department with a detailed statement, duly sworn to and subscribed, showing the number of times each and every barge has removed shells from the above described beds or water bottoms during the preceding month, the location from whence removed, the dates when same shells were removed, and the quantities of shell so removed; and it shall accompany same with full payment therefor. This statement shall not be conclusive upon the Department, and it reserves the right, and each said LESSEE so agrees, to permit the Department's authorized representative to examine any and all of each LESSEE'S books, records and memoranda of whatever kind or nature, pertaining to or having any connection whatever with the removal or sale of said shells.

11.

The Department further reserves the right, and each LESSEE agrees, to have the Department's agents or representatives inspect the barges, boats, and dredges, etc., in which the said shells are removed, and to keep a check on the number thereof, and also to determine by whatever mean it may deem necessary, the number of cubic yards of shells which have been removed from the hereinabove described beds or water bottoms, and to require the payment therefor.

12.

LESSEES agree that the quantity of shells removed by LESSEES will yield to the Department not less than ONE HUNDRED THOUSAND DOLLARS ($100,000.00) per year, starting with the year beginning on the date hereof, and continuing therefrom throughout the life of this Contract. LESSEES further agree that in the event for any reason LESSEES do not remove sufficient shells to aggregate in total, at the price per yard stipulated above, the guaranteed yield to the Department of ONE HUNDRED THOUSAND DOLLARS ($100,000.00) per year, LESSEES will pay to the Department an amount sufficient to produce the minimum sum of ONE HUNDRED THOUSAND DOLLARS ($100,000.00) per year as stipulated.

13.

In case any LESSEE fails to make payment according to the reservations, terms and conditions hereinabove stipulated within the time provided in this agreement, or should any LESSEE fail or refuse to comply with any provisions in this agreement, on and after ten (10) days from the date said payments are due, or said failure or refusal to comply herewith, this agreement shall be automatically revoked, terminated and canceled as to the offending provided that the LESSEE shall be given written notice of any such failure to comply with a provision of this Agreement, and LESSEES shall have five (5) days after receipt of such notice in which to correct such default. In the event such default is not cured within the said five (5) day period, then this Agreement shall be terminated without further formality, except for a written notice of such revocation and termination to be forwarded by the Secretary for the Department to such LESSEE at its domicile and to the Clerks of Court in the Parishes wherein the hereinabove described Lakes are located, by United States mail, postage prepaid. Nothing to the contrary withstanding the provisions of this paragraph shall not release or relieve each LESSEE, its successors and assigns from the liability assumed and established in paragraphs 6 and 7 of this Agreement, arising on or before the date of cancellation or forfeiture of the rights and privileges herein provided.

14.

The privilege of assigning this Agreement by any LESSEE is acknowledged, but such assignment shall not be binding upon the Department until it has been furnished with written notice of the assignment, together with a copy thereof, approved by the Department, except that such approval shall not be required if such assignment and all rights hereunder are made to a bona fide successor or subsidiary of said LESSEES, or if pledged as collateral security for any and all purposes whatsoever. It is expressly understood, however, that any one of said LESSEES, with the written approval of the Department, may issue to any person, firm or corporation of its choice, from time to time, and at any time, permits to take and remove shells and shell deposits from the area covered hereby, and in such event, the LESSEE granting such permit shall contract with such permittee to take or remove shells and shell deposits from the area covered hereby and said LESSEE shall remain liable for the performance of all duties and obligations herein imposed.

15.

LESSEES further agree and obligate themselves to execute, simultaneously with the execution of this Agreement, in favor of the Department, in the manner prescribed by law, a bond in the sum of ONE HUNDRED THOUSAND DOLLARS($100,000.00) with a solvent surety company authorized to do business in Louisiana as surety thereon, conditioned that LESSEES will faithfully, promptly and diligently carry out and perform all of the conditions and obligations herein imposed, described and assumed by this Agreement, which bond shall be renewable annually during the base term of this Agreement or any extended period thereof.

16.

Each LESSEE further agrees, binds and obligates itself before commencing operations in accordance with this Agreement, to furnish the Department a map, plat or chart to scale as specified by the Department of the major areas of the beds and water bottoms hereinabove described and from which such LESSEE shalltake and remove shells and/or shell deposits, which map, plat or chart shall have marked thereon the location at which such LESSEE shall commence its operations; and from time to time, such LESSEE shall notify the Department, in writing, of any and every major change of location of its operations, and by correcting said map, plat or chart aforesaid by marking its new major areas of operation as well as each and every former major area of operation under this Agreement.

17.

Upon the termination of this Agreement, either by the expiration of its terms or by forfeiture or revocation, or for any other cause, the said LESSEES agree and bind themselves immediately to turn over to the

Department all maps, records of borings, and other data relative to said shells and/or shell deposits which it may have obtained, and such maps, records, and other data shall be and remain the property of the Department.

18.

The Department specially reserves the right to permit oyster growers to remove such oyster and/or clam shells from any of said water bottoms or reefs within the area above described in this Contract as may be required by such oyster growers for seeding purposes only, and with which reservation LESSEES acquiesce and consent.

19.

LESSEES agree that in the event the Department shall desire to permit oyster growers to remove oyster and/or clam shells as provided, the Department will furnish to such oyster growers a written order to the aforesaid LESSEES authorizing and directing LESSEES to permit the removal of oyster and/or clam shells by said oyster and/or clam growers.

20.

The Department specifically reserves the right to establish rules and regulations on dredging areas in the interest of living resources and suspend the removal of shells and/or other shell deposits from the above described beds or water bottoms by LESSEES and their successors and assigns in the event that the dredging operations by LESSEES and their successors and assigns violate said regulations. The suspension aforesaid shall remain effective and in full force and effect for such duration or period of time as said dredging operations continue to be in violation of said regulations, cause or produce the damage or damages herein provided and until corrected by LESSEE, and its successors and assigns, to the complete satisfaction of the Department.

21.

No failure or omission by any of the parties hereto in the performance of any obligation imposed by this Contract shall be deemed a breach of this Contract or create any liability for damages if the same shall arise from any cause or causes beyond the control of such party and without the fault or negligence of such party, including acts of God, acts of Federal, State or local government, or any agency thereof, order or directive of any governmental authority or any officer, department, agency or instrumentality thereof, acts of the public enemy, war, rebellion, sabotage, insurrection, riot, invasion or strike. This force majure clause shall not apply to the annual minimum guaranty set forth in item 22 in any lease year in which any of the Purchasers dredge shells under the provisions of this agreement.

22.

The Department does give and grant unto each LESSEE, who has not lost or forfeited its rights hereunder, the right at any time to terminate this Agreement by each such LESSEE, who has not lost or forfeited its rights hereunder jointly, giving to the Department ninety (90) days written notice of such LESSEE'S intention so to do, provided said written notice shall be accompanied by the payment of a termination fee in the sum of FIVE THOUSAND DOLLARS ($5,000.00).

Should this Agreement be terminated at any time other than the end of any lease year, then the ONE HUNDRED THOUSAND DOLLAR ($100,000.00) annual minimum guaranty shall be reduced by the amount of royalty paid by LESSEES to the Department during such lease year, but prior to such termination, to the end that LESSEES in the lease year of termination shall pay not less than the ONE HUNDRED THOUSAND DOLLAR ($100,000.00) minimum annual guaranty. After making said calculation, should it be determined that any part of said annual guaranty shall be due and owing, then such amount shall be paid to the Department along with the FIVE THOUSAND DOLLAR ($5,000.00) termination fee.

The words "lease year", wherever in this item used, shall mean the period beginning on May 18th and ending on the following May 17th. The termination of this Agreement by LESSEES shall not relieve LESSEES of all LESSEES' obligations hereunder arising prior to the effective date of termination.

23.

The contractual rights of each respective LESSEE granted hereunder shall not be abridged by the failure of any other LESSEE'S failure to perform pursuant to this agreement except that the remaining LESSEES shall not be relieved of the obligation to pay the annual minimum guaranty provided in paragraph 22. Cancellation of this agreement as to said offending LESSEE or LESSEES shall in no way affect the other LESSEES or in any way change, alter or amend this Agreement as to them.

24.

If any provisions of this Agreement shall be de-reed invalid or unenforceable, the remainder of the Agreement shall continue in full force and effect.

25.

This document contains the entire agreement between the parties and cannot be changed or terminated orally but only by an agreement in writing and signed by the party against whom enforcement of any waiver, change, modification or discharge is sought.

26.

The Department shall have the right to negotiate with the LESSEES or any of them for the planting of shells for oyster cultivation and to require the LESSEES to deduct the cost of such planting of shells from the royalties due the Department by such LESSEE. The LESSEES agree in good faith to negotiate with the Department for the planting of shells for oyster cultivation and the quantities and value of said shell shall be determined at the time of purchase.

APPENDIX C

PHYSICAL ENVIRONMENT

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APPENDIX C

Introduction

This appendix provides additional technical information concerning certain aspects of the physical and chemical environment that have been discussed in the EIS. These include salinity, physical and chemical characteristics of the water column, and physical and chemical characteristics of bottom sediments.

Salinity

Salinities in Lakes Pontchartrain and Maurepas are influenced by the river systems to the north and west of the lakes and by the saline waters of Lake Borgne, Chandeleur Sound, Mississippi Sound, and Breton Sound to the southeast. Saline water enters the system via the Rigolets and Chef Menteur Pass. The IHNC provides an avenue for saline water from the MR-GO to enter Lake Pontchartrain. Fresh water from the Pearl River system can also enter via these natural tidal passes. The Bonnet Carre' Spillway is periodically utilized to divert Mississippi River water into Lake Pontchartrain during large floods.

Several salinity monitoring stations were analyzed over their periods of record. The stations are Pass Manchac near Ponchatoula, Lake Pontchartrain at Little Woods, Chef Menteur Pass near Lake Borgne, and Lake Pontchartrain at North Shore. Average monthly salinities for their periods of record are shown in Tables C-1 through C-4.

The data indicate that the lowest salinities are generally in the late spring and highest in the summer and late fall. This reflects seasonal variations in freshwater inflows from the major rivers and streams. The salinities of Lakes Pontchartrain and Maurepas normally range from fresh to brackish. Salinities average less than 0.2 ppt in Lake Maurepas while averaging about 4.1 ppt in Lake Pontchartrain. The lowest mean monthly salinity in Lake Pontchartrain (2.6 ppt) occurs in May while the maximum (5.9 ppt) occurs in October. The salinity regime is subject to drastic change during floods on the rivers and streams discharging into Lake Maurepas and Pontchartrain, Bonnet Carre' Spillway openings, and hurricanes.

Analyses of salinity data indicate that the most notable increase in average annual salinity occurred after 1963. The salinity data were further aggregated to the period prior to 1963 and to the period subsequent to 1963. Mean monthly salinities increased for all months for the period subsequent to 1963. This increase can be attributed

TABLE C-1

MEAN MONTHLY SALINITIES (PPT)

PASS MANCHAC NEAR PONCHATOULA, LOUISIANA

Year	January	February	March	April	May	June	July	August	September	October	November	December
1951	.8	.3	.4	.1	.1	.6	.7	1.0	.8	1.4	1.7	2.1
1952	2.3	1.1	.9	.7	-	.8	2.0	2.5	3.2	3.5	4.3	3.6
1953	-	1.1	.7	.7	.2	.6	.5	.8	1.1	1.3	1.6	.7
1954	.3	.6	.7	.6	.8	1.0	1.1	2.1	3.6	3.7	3.8	3.8
1955	2.3	1.7	2.3	1.7	1.6	1.7	2.6	1.7	2.1	2.3	2.4	1.9
1956	2.3	1.0	.5	.8	1.0	1.2	1.4	1.5	2.6	3.6	4.1	3.5
1957	3.2	3.7	2.4	1.3	1.6	2.5	3.4	2.8	2.9	2.5	2.0	.9
1958	.9	.3	.2	.4	.3	.4	.4	.5	.7	1.3	1.0	.9
1959	.9	.5	.4	.3	.5	.2	.4	.2	.3	.2	.4	.3
1960	.3	.3	.3	.3	.4	.4	.6	.7	.7	.6	.7	.9
1961	.6	.4	.1	.1	.2	.3	.2	.2	.3	.3	.2	.2
1962	.1	.1	.1	.1	.2	.2	.2	.4	.5	.9	1.4	1.5
1963	1.2	1.6	2.5	1.6	3.0	3.2	2.8	2.8	4.3	4.8	4.6	3.9
1964	2.2	2.3	.6	.7	.6	1.3	1.2	1.0	1.9	1.6	1.6	.7
1965	1.2	.9	.4	1.0	1.2	1.5	1.4	1.5	2.6	3.1	3.5	3.1
1966	1.7	.8	.4	.4	.5	.6	.6	.8	.9	1.3	1.6	2.5
1967	2.1	1.7	2.0	2.3	1.7	2.3	2.3	2.6	3.3	3.1	3.2	2.9
1968	2.5	2.5	2.6	2.3	2.5	2.8	2.9	2.7	2.9	3.4	3.5	2.6
1969	2.2	2.2	1.9	1.0	.9	1.4	1.7	2.1	2.1	3.0	3.3	3.5
1970	2.7	3.0	3.0	2.7	3.1	3.2	2.8	2.8	2.6	2.5	1.9	1.6
1971	1.2	1.9	1.1	1.4	1.6	1.3	1.6	1.7	1.7	1.3	1.9	1.2
1972	.3	.2	.2	.7	.7	1.0	1.6	1.6	2.7	3.5	3.4	2.2
1973	1.5	1.1	.8	.2	.1	.1	.1	.1	.5	3.0	.6	.6
1974	.7	.1	.3	.1	.4	.3	.4	.4	.8	1.0	1.1	.7
1975	.7	1.0	.8	.8	.2	.1	.1	.6	.1	2.0	.5	.6
1976	.5	.3	.5	.5	.8	1.0	.9	1.3	1.7	2.0	2.0	1.4
1977	1.1	.7	.8	3.5	.4	.9	1.7	1.4	.8	1.1	1.2	.4
1978	-	-	-	-	-	-	-	-	-	.7	1.0	.9
1979	1.3	.5	.5	.4	.1	.1	.3	.4	.6	.7	.7	.6
1980	.6	.6	.6	.1	.0	.2	.6	1.1	1.2	2.2	2.1	1.7
1981	.9	.1	1.7	2.1	2.0	1.6	2.2	1.8	2.1	-	-	-

- No Salinity Measurements Taken

SOURCE: US Environmental Protection Agency (US EPA), STORET SYSTEM

TABLE C-2

MEAN MONTHLY SALINITIES (PPT)

LAKE PONTCHARTRAIN AT LITTLE WOODS

Year	January	February	March	April	May	June	July	August	September	October	November	December
1946	-	.8	.6	.6	.6	.4	.4	.6	2.0	2.1	2.2	2.1
1947	1.3	1.0	.7	.6	.6	-	.8	1.0	2.8	6.6	5.1	4.2
1948	3.2	2.0	1.3	1.3	1.1	1.4	2.1	2.2	3.4	3.0	2.7	2.1
1949	1.3	1.0	.9	.7	.6	.5	.5	.4	1.9	2.6	2.5	3.0
1950	2.6	1.9	.4	.2	.2	.2	.5	1.0	4.1	5.1	4.8	4.5
1951	3.8	2.9	3.0	3.4	1.6	1.8	2.0	2.5	3.9	5.4	4.4	4.3
1952	4.0	3.8	3.5	3.4	3.1	3.0	3.8	5.9	7.7	7.8	8.4	8.1
1953	6.5	6.3	5.1	4.1	3.9	2.4	2.5	2.4	3.3	4.0	4.2	3.1
1954	1.5	1.4	1.6	1.8	2.1	2.6	3.0	5.0	8.5	9.9	9.1	8.0
1955	7.0	5.7	4.8	5.0	3.9	4.4	4.8	4.7	6.0	6.0	6.6	6.4
1956	6.1	4.6	3.5	3.5	3.4	3.3	2.9	4.8	8.2	8.7	9.0	7.5
1957	6.5	6.3	5.8	5.4	4.7	4.6	4.6	4.6	5.1	5.1	5.6	4.3
1958	3.5	3.1	2.7	1.9	1.6	1.6	1.1	1.5	2.6	3.0	2.9	2.9
1959	3.0	2.7	1.7	1.3	1.3	1.2	1.2	.8	1.6	2.1	2.1	1.4
1960	2.1	1.4	1.2	.8	.9	1.7	1.9	2.8	3.1	2.8	2.5	3.3
1961	2.9	2.1	1.2	0.8	1.0	.8	.9	.8	2.6	1.9	1.8	1.2
1962	.6	.3	.5	1.2	1.2	1.2	1.4	3.1	5.2	5.1	6.0	5.9
1963	6.0	4.7	4.5	5.6	5.6	5.9	6.3	6.6	9.5	10.6	11.0	10.0
1964	7.5	6.9	5.3	4.0	4.3	3.9	3.9	3.8	5.4	6.3	6.6	5.6
1965	4.1	3.7	3.2	2.9	3.9	3.5	4.4	5.5	8.1	8.7	8.7	7.5
1966	5.7	6.7	1.9	2.7	2.7	3.2	3.5	3.7	4.4	5.7	5.5	6.4
1967	6.0	5.0	5.5	5.6	5.5	5.9	5.1	6.1	6.6	6.6	7.2	6.7
1968	5.6	5.1	6.0	5.6	5.7	5.8	5.5	5.6	6.4	7.3	7.4	7.2
1969	6.5	5.8	5.8	4.4	3.4	3.7	4.1	5.3	6.3	7.5	7.1	8.4
1970	7.0	6.2	6.1	6.5	5.6	4.9	5.6	6.2	7.0	7.2	5.9	5.2
1971	5.4	5.3	5.2	4.7	5.2	5.8	5.6	6.1	6.4	6.2	6.2	6.7
1972	3.5	2.6	3.0	3.5	2.8	4.1	4.9	5.7	7.2	7.7	8.8	7.0
1973	5.9	4.7	4.9	2.1	.2	.2	1.3	2.5	4.3	3.8	4.1	4.0
1974	2.4	2.1	1.9	2.1	2.0	1.4	1.7	3.3	4.8	5.4	5.4	4.2
1975	3.4	2.5	3.1	2.2	1.2	1.7	1.8	2.1	3.2	3.2	2.5	2.4
1976	2.7	2.7	3.1	3.2	3.1	3.1	2.6	4.5	6.3	7.2	7.2	6.4
1977	5.7	4.9	5.0	4.1	3.4	3.7	4.3	5.6	6.1	4.6	5.4	4.6

- No Salinity Measurements Taken

SOURCE: US EPA, STORET SYSTEM

TABLE C-3

MEAN MONTHLY SALINITIES (PPT)

CHEF MENTEUR PASS NEAR LAKE BORGNE

Year	January	February	March	April	May	June	July	August	September	October	November	December
1957	-	-	6.4	5.3	4.5	4.7	6.0	7.1	9.2	6.7	6.5	4.5
1958	3.7	3.1	2.8	1.9	1.6	1.5	1.7	2.5	4.9	4.2	4.4	4.3
1959	4.4	3.2	2.1	1.8	2.1	1.5	1.5	1.4	4.1	3.9	2.7	2.9
1960	2.0	1.6	1.1	1.1	1.3	3.6	5.1	6.3	5.5	5.0	4.5	5.3
1961	2.8	1.4	.8	1.0	1.5	1.8	2.5	3.5	3.5	2.9	2.6	1.4
1962	.7	.3	.7	1.2	1.7	2.1	3.5	8.4	10.2	9.1	9.8	8.4
1963	7.5	5.7	5.0	5.9	7.8	9.4	9.2	10.5	13.5	13.1	12.4	10.6
1964	8.9	6.8	5.2	3.7	3.7	3.7	4.9	4.9	7.7	7.6	7.5	5.7
1965	4.1	3.7	3.9	3.2	5.4	6.3	6.8	8.2	10.3	-	10.4	9.5
1966	5.7	4.6	2.7	4.5	3.2	3.3	3.8	5.4	6.8	8.2	8.7	8.6
1967	7.6	5.4	5.6	6.3	5.7	6.3	8.0	10.9	9.1	8.6	9.2	8.7
1968	5.4	5.0	6.5	5.8	5.6	5.2	6.4	7.5	8.9	9.2	8.8	7.9
1969	6.4	6.3	5.6	4.4	3.0	4.0	5.3	8.1	8.8	9.5	8.5	10.1
1970	8.1	7.0	6.7	6.1	6.1	5.9	8.1	8.3	9.1	8.6	6.8	7.6
1971	6.4	6.0	4.4	4.4	5.5	5.7	7.9	8.8	8.1	7.0	7.7	6.8
1972	4.1	2.7	2.7	3.7	4.3	5.6	8.9	8.3	11.4	12.5	10.0	8.0
1973	5.8	4.6	3.9	2.1	.3	.3	3.0	6.0	6.6	5.3	5.8	5.1
1974	2.9	2.0	2.2	2.3	2.2	1.7	3.5	6.1	6.6	7.3	6.6	5.2
1975	3.5	2.6	2.8	2.3	1.2	2.2	2.7	2.3	2.3	3.7	3.3	3.4
1976	3.4	3.6	4.2	3.2	3.4	3.4	4.2	8.9	10.7	10.8	10.2	6.8
1977	6.2	5.5	5.5	4.6	3.6	4.8	9.5	9.4	7.3	6.8	6.3	4.9
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	5.3	3.2	2.3	2.2	.6	2.6	3.9	4.7	5.6	6.0	6.6	5.0
1980	3.7	2.7	-	3.2	2.1	2.3	2.0	8.7	9.2	8.9	9.0	7.3
1981	9.5	8.0	-	-	-	-	-	-	-	-	-	-

- No Salinity Measurements Taken

SOURCE: US EPA, STORET SYSTEM

TABLE C-4

MEAN MONTHLY SALINITIES (PPT)

LAKE PONTCHARTRAIN AT NORTH SHORE

Year	January	February	March	April	May	June	July	August	September	October	November	December
1957	-	-	-	-	-	-	5.5	7.3	7.4	5.8	5.6	3.6
1958	2.9	2.8	1.9	1.5	1.2	1.3	1.5	1.5	3.6	3.2	2.8	3.4
1959	4.1	2.3	1.7	1.8	2.0	1.7	1.6	1.4	4.4	3.4	2.0	1.9
1960	1.2	1.0	1.0	.7	1.4	3.8	5.0	5.2	4.2	2.9	3.7	3.9
1961	2.4	2.1	1.0	.6	.8	1.8	1.3	1.6	2.8	2.2	2.3	1.1
1962	.5	.5	.4	.8	1.9	2.0	2.5	7.6	8.4	7.1	7.7	6.8
1963	6.1	4.9	4.1	4.7	5.6	8.2	6.5	8.6	11.7	10.5	10.5	9.1
1964	6.3	5.7	4.0	2.7	2.2	3.3	3.3	3.2	7.5	7.6	6.4	4.9
1965	4.1	2.7	3.0	2.4	4.6	5.1	5.2	6.5	9.2	8.5	8.9	6.8
1966	4.1	3.0	1.8	3.6	3.0	2.5	3.5	-	-	-	-	-
1971	-	-	-	-	-	-	-	6.3	6.6	5.3	5.7	5.9
1972	3.7	2.2	1.9	3.2	4.0	5.3	7.7	5.8	10.4	11.4	8.9	6.1
1973	4.0	3.6	2.9	2.0	1.1	.6	1.9	4.2	6.5	5.2	5.3	3.6
1974	2.8	1.4	1.3	1.2	1.6	1.4	1.8	4.4	5.3	5.3	5.1	3.4
1975	2.9	2.3	1.7	1.7	1.0	1.2	1.1	1.0	2.8	2.1	2.1	2.1
1976	2.5	1.8	2.2	2.0	2.3	2.2	2.6	6.0	8.1	8.1	6.7	4.8
1977	4.0	3.9	3.3	2.7	2.7	3.0	6.6	8.0	5.1	4.5	4.5	3.5
1979	3.3	2.2	1.4	1.2	1.0	.9	2.0	3.4	3.6	3.9	4.5	3.1
1980	2.2	2.0	2.1	.9	.6	.8	4.6	5.6	6.6	6.1	7.0	5.0
1981	6.1	6.3	5.6	5.0	6.7	5.8	5.1	7.5	7.5	-	-	-

* No Salinity Measurements Taken During 1967-1970 and 1978
- No Salinity Measurements Taken

SOURCE: US EPA, STORET SYSTEM

primarily to the completion of the MR-GO in 1963 which provided a major access for saline water to enter Lakes Maurepas, Pontchartrain, and Borgne. Salinity data aggregated for pre and post MR-GO conditions are shown in Table C-5.

Analysis of monthly summaries of salinity for pre and post MR-GO conditions indicates that mean annual salinities have increased by:

- 1.1 ppt at Lake Pontchartrain, North Shore
- 1.8 ppt at Lake Pontchartrain, Little Woods
- 0.2 ppt at Pass Manchac near Pontchatoula
- 2.0 ppt at Chef Menteur Pass near Lake Borgne

Table C-5 shows that all of the post MR-GO mean monthly salinities for the four stations are greater than or equal to 1.0 ppt. Analysis of Tables C-1 through C-4 indicates the following frequencies of low salinity conditions:

- Pass Manchac near Pontchatoula - 40% of post MR-GO mean monthly salinities are less than 1.0 ppt.
- Lake Pontchartrain at Little Woods - 1% of post MR-GO mean monthly salinities are less than 1.0 ppt.
- Chef Menteur Pass near Lake Borgne - 2% of post MR-GO mean monthly salinities are less than 1.0 ppt.
- Lake Pontchartrain at North Shore - 3% of post MR-GO mean monthly salinities are less than 1.0 ppt.

TABLE C-5

MEAN MONTHLY PRE AND POST MR-GO SALINITIES (PPT)

STATION NAME	JAN PRE/POST MR-GO	FEB PRE/POST MR-GO	MAR PRE/POST MR-GO	APR PRE/POST MR-GO	MAY PRE/POST MR-GO	JUN PRE/POST MR-GO	JUL PRE/POST MR-GO	AUG PRE/POST MR-GO	SEP PRE/POST MR-GO	OCT PRE/POST MR-GO	NOV PRE/POST MR-GO	DEC PRE/POST MR-GO
Pass Manchac Near Pontchatoula 1/	1.3 1.4	1.0 1.2	0.9 1.1	0.7 1.2	0.8 1.0	1.0 1.2	1.3 1.3	1.2 1.5	1.6 1.8	1.8 2.2	2.0 2.1	1.7 1.7
Lake Pontchartrain At North Shore 2/	2.9 3.8	2.3 3.1	1.7 2.6	1.7 2.4	2.2 2.6	3.1 2.7	2.9 4.0	4.1 5.4	5.1 7.0	4.1 6.5	4.0 6.3	3.5 4.9
Lake Pontchartrain At Little Woods 3/	3.6 5.1	2.9 4.6	2.4 4.3	2.3 3.8	2.1 3.5	2.2 3.6	2.0 4.0	2.6 4.8	4.2 6.1	4.8 6.5	4.7 6.6	4.3 6.2
Chef Menteur Pass Near Lake Borgne 4/	3.5 5.7	2.6 4.7	2.7 4.3	2.6 3.9	2.9 3.5	3.5 4.0	3.4 5.8	4.9 7.5	6.2 8.4	5.3 8.3	5.1 8.1	4.5 7.1

1/ Pre MR-GO 1951-1963, Post MR-GO 1963-1981

2/ Pre MR-GO 1957-1963, Post MR-GO 1963-1981

3/ Pre MR-GO 1946-1963, Post MR-GO 1963-1977

4/ Pre MR-GO 1957-1963, Post MR-GO 1963-1981

SOURCE: US EPA, STORET SYSTEM

Salinity readings were also taken in Lake Pontchartrain at the north end of the Causeway near Mandeville and in the middle of the Causeway. The readings cover the post MR-GO period from 1971 to 1981. Eighteen percent of the readings from the north end of the Causeway were less than 1.0 ppt while only 10% of the readings at the middle of the Causeway were less than 1.0 ppt.

These salinity data indicate that low salinity conditions (less than 1 ppt) seldom occur except in the northwest area of the lake. Bonnet Carre' Spillway openings, however, increase the extent and duration of low salinity conditions over the entire lake.

The MR-GO is not the only factor that contributes to increased salinities. Many canals and channels, which provide avenues for saltwater intrusion, have been dredged in the Lake Pontchartrain Basin.

Salinity data available indicate that the salinity regime in the Lake Pontchartrain Basin has become somewhat stabilized in the period since 1963. Although there remains no significant increase in mean annual salinity, salinity variations may be considerable. During periods of low inflow, salinities may increase to as high as 5.0 ppt in Lake Maurepas and as high as 20 ppt in the vicinity of the IHNC (Schurtz, 1982).

No significant increase in mean annual salinity is projected in the future for Lakes Maurepas and Pontchartrain. Salinity is expected to slightly increase in the Lake Borgne area and surrounding marshes due to future land loss in the area. Salinity would only slightly increase because the open water areas created as a result of land loss would be shallow and not lend themselves easily to saltwater intrusion. The marshes are probably a small percentage of the tidal prism and may not have a significant impact from a hydrologic standpoint. Wide seasonal salinity fluctuations are expected to continue in the future in response to freshwater inflows from major rivers and streams.

General Water Quality

Data for the general quality characterization of Lake Maurepas and Pass Manchac are presented in Table C-6. Summary statistics for data spanning approximately six years (April 1975 to January 1981) are shown for a sampling station located at the approximate center of Lake Maurepas. Similarly, descriptive statistics for data accumulated over a period of about eight years - March 1978 to June 1986 - are shown for a sampling station located in Pass Manchac east of U.S. Highway 51. The Lake Maurepas station has been sampled by the U.S. Geological Survey-Water Resources Division. The Louisiana Department of Environmental Quality has sampled the Pass Manchac station approximately monthly.

Because of the close proximity of the two waterbodies, data for many general water quality parameters are quite similar for the two sampling locations. However, significant differences in the computed means of some constituents likely result from the relative influence of periodic tidal inflow from Lake Pontchartrain to Lake Maurepas via Pass Manchac.

Measured water temperatures of both locations averaged between 21 and 22°C over the respective periods of record, and the distributions of individual water temperature measurements at the two locations are almost identical. During each of the respective periods of record, one water temperature measurement at each location was recorded that was higher than the 32°C state standard. This was probably due to natural causes, which is acceptable according to the state standards.

The mean of the dissolved oxygen record for the Lake Maurepas sampling location is 8.2 mg/L. None of the dissolved oxygen measurements at this location were below the 5.0 mg/L state standard. The average of the dissolved oxygen record for the Pass Manchac sampling station is 8.1 mg/L. Three of the 99 dissolved oxygen measurements at this location were less than the 5.0 mg/L state standard. Comparisons of measured dissolved oxygen concentrations with computed dissolved oxygen saturation

TABLE C-6

MEASURES OF GENERAL WATER QUALITY - LAKE MAUREPAS AND PASS MANCHAC

	Middle of Lake Maurepas Near Machac, LA 1/	Pass Manchac, East of U.S. Highway 51 2/
Water Temperature °C		
Number of Observations	33	99
Mean	21.3	21.7
Range	7.5-32.5	6.5-34.0
Period of Record	4/75-5/77	3/78-6/86
Dissolved Oxygen, mg/L		
Number of Observations	134	99
Mean	8.2	8.1
Range	5.4-13.2	4.1-12.5
Period of Record	4/75-1/81	3/78-6/86
Dissolved Oxygen Saturation, %		
Number of Observations	32	61
Mean	97.7	91.0
Range	78.4-130.8	50.0-123.0
Period of Record	4/75-5/77	3/78-4/83
5-Day Biochemical Oxygen Demand, mg/L		
Number of Observations	131	-
Mean	1.4	-
Range	0.0-8.3	-
Period of Record	4/75-1/81	-
Total Organic Carbon, mg/L-C		
Number of Observation	129	83
Mean	9.3	7.8
Range	3.2-25.0	2.2-16.9
Period of Record	4/75-1/81	10/78-6/86
Chemical Oxygen Demand (High Level) mg/L		
Number of Observations	111	90
Mean	30	54
Range	5-95	0-175
Period of Record	1/76-1/81	3/78-6/86
pH, field, standard units		
Number of Observations	140	99
Mean	7.1	7.1
Range	6.1-7.9	6.5-8.0
Period of Record	4/75-1/81	3/78-6/86

TABLE C-6 (Continued)

MEASURES OF GENERAL WATER QUALITY - LAKE MAUREPAS AND PASS MANCHAC

	Middle of Lake Maurepas Near Machac, LA 1/	Pass Manchac, East of U.S. Highway 51 2/
Total Alkalinity, mg/L as $CaCO_3$		
Number of Observations	140	92
Mean	23	35
Range	8-59	17-59
Period of Record	4/75-1/81	3/78-6/86
Total Dissolved Solids, mg/L		
Number of Observations	-	92
Mean	-	1442
Range	-	30-6,846
Period of Record	-	3/78-6/86
Total Chloride, mg/L		
Number of Observations	140	94
Mean	160	809
Range	7-1,200	19-6,125
Period of Record	4/75-1/81	3/78-6/86
Total Sulfate, mg/L		
Number of Observations	139	87
Mean	28	95
Range	3-180	8-483
Period of Record	4/75-1/81	3/78-6/86
Total Non-filterable Residue, mg/L		
Number of Observations	94	94
Mean	19	26
Range	0-376	0-204
Period of Record	4/77-1/81	3/78-6/86
Turbidity, JTU		
Number of Observations	135	58
Mean	21	20
Range	2-220	2-135
Period of Record	4/75-1/81	3/78-4/83
Color, PT-CO units		
Number of Observations	138	98
Mean	52	39
Range	3-160	10-100
Period of Record	4/75-1/81	3/78-6/86

TABLE C-6 (Continued)

MEASURES OF GENERAL WATER QUALITY - LAKE MAUREPAS AND PASS MANCHAC

	Middle of Lake Maurepas Near Machac, LA 1/	Pass Manchac, East of U.S. Highway 51 2/
Nitrite plus Nitrate, ug/L-N		
Number of Observations	138	98
Mean	219	140
Range	0-1,300	10-740
Period of Record	4/75-1/81	3/78-6/86
Total Phosphorus, ug/L-P		
Number of Observations	138	97
Mean	142	101
Range	10-1,700	20-340
Period of Record	4/75-1/81	3/78-6/86

1/ Middle of Lake Maurepas near Manchac, LA (112WRD 301500090300000) 4/75 to 1/81. About one third of the data (about 50 samples) were accumulated during the period April 16, 1979 to June 14, 1979.

2/ Pass Manchac, East of U. S. Highway 51 (21LA10PS B041705010) 3/78-4/83. Samples have been collected at approximately one month intervals over the period of record.

values were made for concurrent temperature-dissolved oxygen measurements for each location. The results of those comparisons indicate that dissolved oxygen content as a percentage saturation averages about 97.7 percent for the Lake Maurepas data and about 91.0 percent for the Pass Manchac data. Three (9 percent) of the 32 concurrent temperature-dissolved oxygen measurements for Lake Maurepas indicate dissolved oxygen concentrations outside of the normally desirable 80 to 120 percent of saturation range. Similarly, review of the 61 concurrent temperature -dissolved oxygen measurements for Pass Manchac showed twelve (20 percent) dissolved oxygen concentrations outside of the normally desirable 80 to 120 percent of saturation range.

The record of 5-day biochemical oxygen demand (BOD5) measurements for the Lake Maurepas sampling station averages 1.4 mg/L; individual observations range from 0.0 to 8.3 mg/L. BOD5 was not measured for the Pass Manchac sampling station.

The mean chemical oxygen demand (COD) for the Pass Manchac data is almost twice the mean of the data for Lake Maurepas. The COD data for the Lake Maurepas sampling station range from 5 mg/L to 95 mg/L and average about 30 mg/L. COD data for the Pass Manchac sampling station average about 54 mg/L and range from zero to 175 mg/L. The periods of record of COD observations differ for the two sampling stations. However, the higher mean COD for the Pass Manchac sampling station is most likely reflective of the influence of brackish inflows from Lake Pontchartrain. The two records of total organic carbon (TOC) measurements are generally similar. The mean of the TOC for Lake Maurepas is 9.3 mg/L-C; these data range from 3.2 mg/L-C to 25.0 mg/L-C. The average of the TOC data for Pass Manchac is slightly lower than for Lake Maurepas - about 7.8 mg/L-C. Observations of TOC concentrations for the Pass Manchac sampling location have ranged from 2.2 mg/L-C to 16.9 mg/L-C.

The pH data for both stations indicate that pH was within applicable state standards.

Total alkalinity measurements (a measure of buffer capacity) average about 23 mg/L for the Lake Maurepas data and about 35 mg/L for the Pass Manchac data. The Environmental Protection Agency's quality criteria for water recommend 20 mg/L alkalinity (as calcium carbonate) as a desirable minimum in fresh water. Using this criterion and examining the distributions of total alkalinity measurements suggests that the waters of Lake Maurepas are not well buffered. About 33 percent of the total alkalinity measurements were less than the 20 mg/L criterion. In contrast, only about three percent of the total alkalinity data recorded for the Pass Manchac sampling location indicated concentrations less than 20 mg/L-$CaCO_3$. Again, the apparent higher total alkalinity at the Pass Manchac sampling station probably results from higher relative concentrations of brackish water salts at this location.

The sample means of total dissolved solids, total chloride, and total sulfate are reflective of the influence of inflows from Lake Pontchartrain on values measured at the Lake Maurepas and Pass Manchac sampling locations. Total dissolved solids data for the Pass Manchac sampling station range from 30 mg/L to 6,846 mg/L and average about 1,442 mg/L. About 9 percent of these data were above the 3,000 mg/L state standard for total dissolved solids. The means of the total chloride and total sulfate data for the Pass Manchac sampling station are 809 mg/L and 95 mg/L, respectively. By comparison, chloride and sulfate data average 160 mg/L and 28 mg/L, respectively, for the Lake Maurepas sampling location. Review of the chloride data for Pass Manchac indicates that about 15 percent of the samples collected had chloride concentrations higher than the 1,600 mg/L state standard. None of the chloride data records for the Lake Maurepas sampling location exceeded the applicable 1,600 mg/L standard. The means of total nonfilterable residue (suspended solids) and true color measurements for the two sampling locations are significantly different in magnitude. The mean of the total

nonfilterable residue data for Lake Maurepas is about 19 mg/L; the average of the Pass Manchac data is about 37 percent greater at about 26 mg/L. True color, which generally results from dissolved or colloidal vegetable extracts, is distinguished from apparent color which may result from the presence of both vegetable extracts and suspended solids. The mean of the true color data for Pass Manchac is about 39 PT-CO (platinum-cobalt) units; the average of the Lake Maurepas data is about 33 percent greater at about 52 PT-CO units. The sample means for turbidity measurements for the two sampling locations are comparable - about 21 Jackson Turbidity Units (JTU's) for Lake Maurepas and about 20 JTU's for Pass Manchac.

Both the mean concentrations for the nitrite plus nitrate and total phosphorus data are significantly higher for the Lake Maurepas sampling location compared to the Pass Manchac location. The average of the nitrite plus nitrate data for Lake Maurepas is about 219 ug/L-N - about 56 percent greater than the 140 ug/L-N mean for Pass Manchac. The mean of the total phosphorus data for Lake Maurepas is about 142 ug/L-P - about 41 percent greater than the 101 ug/L-P mean of the Pass Manchac data. Generally, these data suggest that Lake Maurepas functions as a nutrient sink, removing much of the nutrient load of its upstream tributaries from the water column.

Water quality data used to assess the general character of Lake Pontchartrain are presented in Table C-7. Descriptive statistics for fourteen general water quality parameters measured at eight sampling locations within the lake and major outlet passes are shown.

TABLE C-7

MEASURES OF GENERAL WATER QUALITY - LAKE PONTCHARTRAIN

STATION	1	2	3	4	5	6	7	8
Water Temperature, °C								
Number of Observations	57	43	43	44	99	98	39	42
Mean	20.5	20.3	20.4	20.7	20.7	20.9	20.1	20.1
Range	5.0-33.0	7.5-33.0	9.5-32.0	8.0-30.5	6.3-32.0	6.0-34.6	8.0-31.5	7.5-32.5
Period of Record	1/75-7/84	1/75-5/77	1/75-5/77	1/75-5/77	3/78-6/86	3/78-6/86	1/75-6/76	1/75-10/83
Dissolved Oxygen, mg/L								
Number of Observations	173	156	155	157	98	97	158	153
Mean	8.0	7.6	7.6	8.3	8.2	8.3	8.7	8.7
Range	4.4-13.0	1.2-12.4	3.7-13.4	3.9-14.2	4.9-12.1	4.9-13.0	6.0-13.6	6.4-13.6
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	3/78-6/86	3/78-6/86	6/74-1/81	6/74-1/81
Dissolved Oxygen Saturation, %								
Number of Observations					53	53		
Mean					88.7	88.2		
Range					64.0-103.0	36.5-106.0		
Period of Record					3/78-8/82	3/78-8/82		
5-Day Biochemical Oxygen Demand, mg/L								
Number of Observations	167	154	151	152			155	148
Mean	1.4	1.5	1.6	1.7			1.7	1.6
Range	0.0-6.5	0.2-6.5	0.0-9.0	0.0-7.3			0.0-11.0	0.0-7.7
Period of Record	6/74-4/84	6/74-1/81	6/74-1/81	6/74-1/81			6/74-1/81	6/74-1/81
Total Organic Carbon, mg/L-C								
Number of Observations	166	147	149	147	83	76	150	141
Mean	9.1	8.1	9.0	8.8	6.4	5.6	6.6	7.3
Range	3.4-25.0	0.0-25.0	1.3-22.0	2.3-28.0	0.3-55.3	2.5-25.0	3.0-31.0	3.6-17.0
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	10/78-6/86	10/78-6/86	6/74-1/81	6/74-1/81
Chemical Oxygen Demand (High Level) mg/L								
Number of Observations	126	113	105	99	86	72	91	86
Mean	38	31	41	50	124	156	54	45
Range	5-200	5-120	9-270	9-350	8-349	15-560	9-370	11-270
Period of Record	1/76-7/84	1/76-1/81	1/76-1/81	1/76-1/81	3/78-6/86	4/78-6/86	1/76-1/81	4/76-1/81

TABLE C-7 (Continued)

MEASURES OF GENERAL WATER QUALITY - LAKE PONTCHARTRAIN

STATION	1	2	3	4	5	6	7	8
pH, Field, standard units								
Number of Observations	177	160	159	159	99	98	161	157
Mean	7.13	7.06	7.07	7.34	7.45	7.59	7.66	7.48
Range	6.10-8.00	5.80-8.10	5.70-8.30	6.00-8.30	6.50-8.69	6.70-8.57	6.40-8.60	6.40-8.50
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	3/78-6/86	3/78-6/86	6/74-1/81	6/74-10/83
Total Alkalinity, mg/L as $CaCO_3$								
Number of Observations	177	160	159	159	92	59	161	156
Mean	27	24	24	36	48	49	55	39
Range	10-87	6-78	3-71	6-170	15-326	0-84	12-105	11-117
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	3/78-6/86	3/78-6/86	6/74-1/81	6/74-1/81
Total Non-Filterable Residue, mg/L								
Number of Observations	106	93	90	87	94	76	92	89
Mean	29	25	18	18	29	25	21	20
Range	0-270	0-334	0-148	0-178	0-336	2-280	0-90	0-190
Period of Record	5/77-7/84	4/77-1/81	4/77-1/81	4/77-1/81	3/78-6/86	3/78-6/86	4/77-1/81	4/77-1/81
Turbidity, JTU								
Number of Observations	151	148	147	147			149	145
Mean	22.1	21.2	15.4	11.2			17.2	14.6
Range	2.0-80.0	1.0-150.0	1.0-100.0	2.0-70.0			0.0-60.0	1.0-100.0
Period of Record	10/74-9/80	10/74-9/80	10/74-9/80	10/74-9/80			10/74-9/80	10/74-7/80
True Color, PT-CO units								
Number of Observations	176	160	157	158	98	95	160	155
Mean	43	39	42	27	21	20	16	19
Range	0-160	0-100	0-140	0-130	5-60	5-50	0-60	0-120
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	3/78-6/86	3/78-6/86	6/74-1/81	6/74-1/81

TABLE C-7 (Continued)

MEASURES OF GENERAL WATER QUALITY - LAKE PONTCHARTRAIN

STATION	1	2	3	4	5	6	7	8
Nitrite plus Nitrate, mg/L-N								
Number of Observations	168	152	148	148	98	97	152	144
Mean	0.24	0.23	0.16	0.13	0.08	0.08	0.56	0.15
Range	0.00-1.40	0.00-1.40	0.00-1.30	0.00-1.60	0.01-1.30	0.00-1.52	0.00-1.90	0.00-2.50
Period of Record	10/74-7/84	10/74-1/81	4/77-1/81	10/74-1/81	3/78-6/86	3/78-6/86	10/74-1/81	10/74-1/81
Total Phosphorus, mg/L-P								
Number of Observations	177	160	157	156	97	95	160	154
Mean	0.136	0.114	0.091	0.087	0.076	0.092	0.112	0.096
Range	0.010-4.200	0.010-1.000	0.010-1.100	0.010-2.50	0.010-0.350	0.020-0.800	0.010-2.70	0.010-2.50
Period of Record	6/74-7/84	6/74-1/81	6/74-1/81	6/74-1/81	3/78-6/86	3/78-6/86	6/74-1/81	6/74-1/81

Sampling Station Number	Location
1	Lake Pontchartrain at Pass Manchac near Manchac, Louisiana
2	Lake Pontchartrain at the mouth of the Tangipahoa River near Lee Landing, Louisiana
3	Lake Pontchartrain at the mouth of the Tchefuncte River near Madisonville, Louisiana
4	Lake Pontchartrain at the mouth of Bayou LaCombe near LaCombe, Louisiana
5	Pass Rigolets at the US Highway 90 Bridge
6	Chef Menteur Pass at the US Highway 90 Bridge
7	Lake Pontchartrain at the Inner Harbor Navigation Canal at New Orleans, Louisiana
8	Lake Pontchartrain at Mid-Causeway

Approximately one-third of the data for sampling stations 1, 2, 3, 4, 7, and 8 were accumulated during the two-month period from mid-April to mid-June 1979. About 50 of the total number of samples from each location were collected as part of an intensive water quality monitoring effort during and immediately after diversion of flood waters through the Bonnet Carre' Floodway. Although these data were accumulated during a rare event, Bonnet Carre' diversions will continue to occur from time to

time. Therefore, the data are included in characterizing Lake Pontchartrain water quality. During all other times data have been collected approximately monthly. At stations 5 and 6, samples have generally been collected monthly.

The computed mean values of the listed parameters are fairly consistent for the eight sampling locations. In general, the means of water temperature observations are about 20°C, and those for dissolved oxygen about 8 mg/L. The distribution of water temperature sample means ranges from 20.1°C to 20.9°C and actual recorded water temperatures range from 5°C to 34.6°C.

Some of the recorded water temperatures were above the 32°C state standard for the lake. This was probably due to natural causes which is acceptable according to the standards. Average low temperatures of about 8 to 10°C occur in December through January. Maximum temperatures of about 30 to 31°C occur from June through September. Introduction of colder Mississippi River flood waters during operation of the Bonnet Carre' Floodway lowers the average spring water temperature in the lake, but the lake returns to its normal maximum by summer. Heavy rains can also locally depress water temperatures via increased river and storm discharges. Again, the lake generally returns to its norm relatively rapidly. High discharges from the Pearl River can bring cooler waters into the lake via flood tides in the Rigolets. The highest mean dissolved oxygen concentration, 8.7 mg/L, was computed from data for sampling stations at the Inner Harbor Navigation Canal (Station 7) and at mid-lake at the Causeway (Station 8). The lowest mean dissolved oxygen concentration, 7.6 mg/L, was computed from data for sampling stations located near the Tangipahoa and Tchefuncte Rivers. Dissolved oxygen concentrations below the 4.0 mg/L state standard have been noted in the lake near the Tangipahoa and Tchefuncte Rivers and Bayou LaCombe (sampling stations 2, 3, and 4, respectively). Four of the 156 observations for station 2, five of the 155 observations for Station 3, and one of the 157 observations for station 4 were less than the state dissolved oxygen standard. Concurrent dissolved oxygen-temperature data

indicate that dissolved oxygen concentrations as a percentage of saturation values average about 90 percent throughout the lake.

Mean values of BOD5 are similar at all stations, ranging from 1.4 to 1.7 mg/L. Collectively, the values range from 0 mg/L to 11 mg/L. The highest recorded BOD5, 11.0 mg/L, was measured at the sampling station near the IHNC (Station 7). This maximum value is about 22 percent higher than the maximum recorded for any of the other sampling locations.

Total organic carbon measurements indicate the amount of organic matter present in water. The measurements of TOC range from 0 to 55 mg/L. Sample means range from 5.6 mg/L at Chef Menteur Pass (Station 6) to 9.1 mg/L at the station near Pass Manchac (Station 1).

Chemical oxygen demand is another measure of organic content in water. Sample means of COD range from 31 mg/L to 156 mg/L, with the greatest mean concentration located at Chef Menteur Pass (Station 6). The measurements range from 5 mg/L to 560 mg/L, with the greatest reading located at station 6.

Examination of the data for pH reveals relatively infrequent instances of measured values below the 6.5 minimum state standard, while there were no instances of pH exceeding the maximum standard of 9.0. The majority of the instances of low pH occurred at the stations located near the Tangipanoa and Tchefuncte Rivers (Stations 2 and 3), where approximately 10 percent of the pH readings were below the state standard. The range of pH values at these stations is from 5.7 to 8.7. The mean values for the stations, range from 7.1 to 7.7.

The distribution of total alkalinity sample means ranges from about 24 mg/L-CaCO3 for sampling stations located near the Tangipahoa and Tchefuncte Rivers (Stations 2 and 3) to about 55 mg/l-CaCO3 for the station near the IHNC (Station 7). Overall, total alkalinity levels ranged from 0 mg/L-CACO3 to 326 mg/L-CACO3 and average about 36

mg/L-CACO3. Sampling locations having the lowest total alkalinity generally correspond to those having the lowest pH.

Measurements of total nonfilterable residue (suspended solids) at the various locations in Lake Pontchartrain range from zero to 336 mg/L and average about 23 mg/L. The station means are fairly consistent, ranging from 18 mg/L to 29 mg/L. Turbidity closely follows the same pattern as suspended solids. Station means range from 11 JTU's near Bayou LaCombe (Station 4) to 22 JTU's near Pass Manchac (Station 1). Collectively, turbidity measurements average about 17 JTU's and range from zero to 150 JTU's.

Aggregated data for true color measurements range from zero to 160 PT-CO units and average about 28 PT-CO units. The distribution of station means ranges from about 16 PT-CO units near the IHNC (Station 7) to about 43 PT-CO units near Pass Manchac (Station 1).

Observations of total nitrite plus nitrate concentrations in Lake Pontchartrain range from zero to 2.5 mg/L-N. The station means are similar, with mean concentrations ranging from 0.08 mg/L-N to 0.56 mg/L-N. The highest mean concentration of 0.56 mg/L-N was near the IHNC (Station 7).

Observations of total phosphorus concentrations in the lake average about 0.1 mg/L-P overall. The station means are consistent, with values all close to the 0.1 mg/L-P total mean. The range of values does vary widely from 0.01 mg/L-P to 4.2 mg/L-P. The highest reading and mean concentrations were observed at Station 1 near Pass Manchac.

Sediment Quality - Contaminants

Sediment composition is an indicator of sources of contamination from diffuse inputs that are not readily discernible as point sources. Also, one of the major concerns of shell dredging's effect on water quality is the potential release of contaminants from the bottom sediments to the

water column. Therefore, the determination of the location and extent of contaminated sediments is essential in assessing potential water quality impacts of shell dredging.

The most recent extensive sediment composition data available were obtained by DEQ as part of a "Water Quality Investigation of Environmental Conditions in Lake Pontchartrain". This sampling and analysis program was performed in 1982 and 1983. The locations and station numbers of the DEQ sampling stations, are indicated on Figure C-1.

Tables C-3 through C-12 present the results of selected heavy metals analyses in sediment samples collected for the DEQ report. The concentrations of the fourteen metals (thirteen priority pollutant metals and barium) in the surficial sediments of the southern shoreline of Lake Pontchartrain revealed maxima at the mouths of the outfall canals at LP02 (Duncan Canal), LP04 (17th Street Canal), LP05 (Bayou St. John), and LP07 (IHNC) during most of the sampling collections of 1982-83. With the exception of zinc, metal concentrations were consistently higher near the 17th Street Canal than at the other stations. There was a discernible eastward pattern in the concentration gradients of the various metals in the sediments. Elevated concentrations of these metals were located generally in the area between the Lake Pontchartrain Causeway and the New Orleans Lakefront Airport.

Seasonal trends were observed for certain metals at all of the southern nearshore stations surveyed. The concentrations of selenium and beryllium were elevated at all stations during the spring 1982 collection, of cadmium in the fall 1982 collection, and of arsenic in the winter 1983 collection.

The concentrations of most of the examined metals were lower in the surficial sediments collected off the northern shoreline of Lake Pontchartrain than those taken near the southern shoreline. However, the stations at the mouths of Bayous Liberty and Bonfouca exhibited high

TABLE C-8

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected March 31, 1982)

Sample (Concentrations)	Metal: Zn	Cu	Pb	Ni	Ag	Be	Cr
SEDIMENT ug/g (ppm) dry weight							
LP02 S	37.5	12.6	9.44	5.05	0.157	0.210	9.20
LP07 S	201.0	30.7	66.6	7.00	0.206	0.364	30.7
LP09 S	61.3	22.4	14.0	8.80	0.091	0.542	23.4
LP10 S	34.7	13.8	16.0	6.08	0.043	0.346	20.8
LP11 S	87.8	28.0	43.9	10.7	0.176	1.14	17.6
LP12 S	82.8	25.2	35.7	9.89	0.181	1.55	15.5
LP13 S	80.6	22.7	30.5	8.24	0.124	2.20	17.7
LP14 S	73.6	23.8	35.2	8.15	0.112	0.859	25.6
LP15 S	47.4	13.6	15.8	6.53	0.069	0.392	10.9
LP16 S	36.4	11.7	13.4	6.13	0.052	0.418	12.2

TABLE C-8 (Continued)

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected March 31, 1982)

Sample (Concentrations)	Metal: Hg	Cd	Tl	Se	Sb	As	Ba
SEDIMENT ug/g (ppm) dry weight							
LP02 S	ND	0.260	0.067	0.221	ND	0.822	54.8
LP07 S	0.118	0.854	ND	0.214	0.030	1.06	89.8
LP09 S	ND	0.290	0.488	0.482	ND	0.634	39.8
LP10 S	ND	0.199	0.499	1.18	ND	0.577	29.6
LP11 S	0.061	0.942	0.166	0.308	ND	0.899	130.
LP12 S	0.024	0.498	0.155	0.301	ND	0.284	106.
LP13 S	0.004	0.468	0.378	0.414	0.015	1.67	76.3
LP14 S	0.013	0.291	0.382	0.533	0.122	3.10	68.4
LP15 S	0.027	0.243	1.43	0.174	ND	0.534	63.6
LP16 S	0.023	0.240	0.120	0.691	ND	0.380	67.4

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-9

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected June 29, 1982)

ug/g dry weight (ppm)

Sample	Zn	Cu	Pb	Ni	Ag	Be	Cr
LP01	33.0	4.05	6.47	17.2	0.070	0.031	19.6
LP03	35.1	3.27	9.31	11.6	0.101	0.134	19.6
LP04	220	33.9	212.	34.7	0.779	0.355	42.9
LP05	57.0	7.77	33.4	13.9	0.153	0.475	20.9
LP07	141.0	7.33	42.6	28.1	2.74	0.280	25.1
LP10	63.0	12.4	11.9	27.9	0.068	1.00	41.5
LP11	109.0	8.62	32.7	39.5	0.142	0.377	29.9
LP12	75.0	5.72	20.9	35.8	0.186	1.32	51.3
LP16	46.5	4.41	9.91	44.9	0.044	0.155	90.1

AD-A186 640 CLAM SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS 4/5
LOUISIANA VOLUME (U) ARMY ENGINEER DISTRICT NEW
ORLEANS LA D L CHEW NOV 87

UNCLASSIFIED F/G 8/1 NL

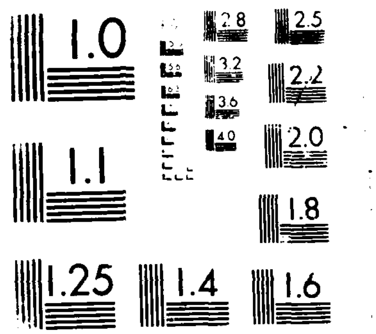
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

TABLE C-9 (Continued)

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected June 29, 1982)

ug/g dry weight (ppm)

Sample	Hg	Cd	Tl	Se	Sb	As	Bb
LP01	0.059	0.277	ND	0..372	0.009	0.353	22.0
LP03	0.083	0.133	0.015	ND	ND	0.167	15.5
LP04	0.402	0.762	0.263	0.838	0.125	0.723	56.4
LP05	0.108	0.215	ND	0.079	0.084	0.134	51.9
LP07	0.195	0.484	ND	0.461	0.092	0.531	29.4
LP10	0.112	0.158	0.010	ND	0.159	0.247	59.6
LP11	0.158	0.303	0.036	0.316	0.475	0.266	12.9
LP12	0.134	0.284	0.044	0.053	0.097	1.517	27.7
LP16	0.025	0.119	0.091	0.354	0.039	0.515	56.8

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-10

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected September 28, 1982)

ug/g dry weight (ppm)

Sample	Zn	Cu	Pb	Ni	Ag	Be	Cr
LP03	41.1	9.5	12.5	7.4	0.369	0.029	15.10
LP04	40.1	22.0	216.2	16.1	1.2	0.071	53.9
LP06	45.2	14.1	26.1	8.5	0.499	0.056	19.3
LP07	140.	10.2	23.4	10.3	0.247	0.039	24.7
LP10	49.4	9.5	10.9	18.2	0.034	0.082	20.9
LP11	74.1	19.0	23.3	20.9	0.115	0.119	43.5
LP12	61.3	13.0	16.2	18.5	0.097	0.067	39.1
LP15	43.0	13.1	6.25	12.9	0.047	0.054	27.56
SC14	73.5	18.9	15.9	17.7	0.170	0.074	42.4
SC25	59.5	15.6	15.1	16.8	0.134	0.067	41.2

TABLE C-10 (Continued)

Concentrations of selected heavy metals for surface sediment samples from Lake Pontchartrain (Collected September 28, 1982)

ug/g dry weight (ppm)

Sample	Hg	Cd	Tl	Se	Sb	As	Bb
LP03	0.063	2.47	0.050	ND	ND	0.434	6.30
LP04	0.447	4.14	0.162	ND	ND	0.624	57.2
LP06	0.088	2.05	0.045	ND	0.012	0.292	9.77
LP07	0.138	1.28	0.183	ND	0.004	0.474	2.27
LP10	0.085	1.40	0.125	ND	ND	0.740	ND
LP11	0.128	1.60	0.130	ND	ND	0.649	3.13
LP12	0.107	1.25	0.143	ND	0.007	0.579	7.83
LP15	0.069	1.33	0.173	ND	ND	0.691	6.27
SC14	0.099	1.99	0.349	ND	ND	0.687	4.10
SC25	0.130	2.57	0.161	ND	ND	0.410	4.97

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-11

Concentrations of Selected Heavy Metals for Surface Sediment Samples from Lake Pontchartrain (Collected September 28, 1982)

ug/g dry weight (ppm)

Sample	Zn	Cu	Pb	Ni	Ag	Be	Cr
LP02	54.3	8.0	1.0	24.3	ND	ND	6.9
LP04	247.2	82.7	266.6	0.1	0.011	0.255	23.3
LP06	42.3	9.7	20.0	9.8	0.136	0.063	6.5
LP07	139.9	16.3	39.0	7.3	0.090	0.176	4.9
LP09	73.6	34.3	8.6	16.7	0.043	0.372	18.1
LP10	68.4	23.2	10.4	13.0	0.024	0.444	20.0
LP11	111.5	27.5	94.0	32.7	ND	0.052	23.9
LP12	75.1	22.3	22.4	19.8	0.045	0.382	27.7
SC14	80.6	18.3	10.9	12.8	0.083	0.482	19.6
LP15	58.4	15.2	4.4	13.7	0.033	0.394	17.3
SC25	82.7	18.1	28.3	19.1	0.067	0.316	21.2

TABLE C-11 (Continued)

Concentrations of Selected Heavy Metals for Surface Sediment Samples from Lake Pontchartrain (Collected September 28, 1982)

ug/g dry weight (ppm)

Sample	Hg	Cd	Tl	Se	Sb	As	Bb
LP02	0.061	1.89	ND	ND	ND	7.22	30.5
LP04	0.223	0.17	0.005	ND	ND	4.57	144.8
LP06	0.076	0.24	0.016	ND	ND	2.62	48.8
LP07	0.269	0.80	0.285	ND	ND	6.69	503.
LP09	0.046	0.70	0.140	ND	ND	5.29	75.4
LP10	0.046	0.55	0.424	ND	ND	5.42	110.0
LP11	0.078	0.75	0.157	ND	ND	4.40	195.
LP12	0.059	0.63	0.159	ND	ND	3.49	192.
SC14	0.046	0.83	0.153	ND	ND	5.91	91.7
LP15	0.024	ND	0.161	ND	ND	5.41	85.8
SC25	0.012	0.68	0.074	ND	ND	5.62	156.

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE 12

Concentrations of Selected Heavy Metals for Surface Sediment Samples from Lake Pontchartrain (Collected April 27, 1983)

ug/g dry weight (ppm)

Sample	Be	Hg	Pb	Cu	Ni	Ba	Cd	Zn	As	Ag
NC5	0.696	0.022	4.88	17.5	26.4	7.06	0.419	87.7	1.60	0.100
NC23	0.343	0.015	4.21	6.66	14.8	4.81	0.760	41.9	0.84	0.056
NE5	0.445	ND	1.72	6.80	18.0	13.0	1.27	161.0	3.340	0.088
NW16	0.474	0.036	2.78	7.48	20.2	6.12	0.918	66.2	0.630	0.042
NW27	0.066	ND	0.746	0.487	2.3	4.01	0.344	8.37	0.153	0.009

SOURCE: Louisiana Department of Environmental Quality, 1984.

concentrations of beryllium, cadmium, zinc, and arsenic during the spring collection of 1983, comparable to maximum levels observed at the southern stations.

Table C-13 presents total hydrocarbon content in various sediment samples collected for the DEQ report. Total hydrocarbon concentration (THC) represents analytical quantification of virtually all organic chemicals in a sample including those of probable biogenic, in addition to anthropogenic, origin. In general, the higher the level of THC, the higher the predominance of anthropogenic chemicals. It can be seen that the southern nearshore areas are more contaminated than offshore areas or areas of the north shore. The area just off the 17th Street Canal (Station LP04) is much more contaminated than the rest of the lake as well as the other nearshore areas. This is due to the large amount of urban runoff discharged by the canal. The 17th Street Canal drains the largest area of any of the Metropolitan New Orleans drainage canals.

Tables C-14 through C-18 present the results of selected organic chemical analyses in sediment samples collected for the DEQ report. At least 58 identifiable organic chemicals were detected in quantities that are attributable to anthropogenic input. Of this number, only six are unquestionably synthetic: polychlorinated biphenyls (PCB's) and the pesticides chlordane, nonachlor, heptachlor, and the DDT metabolites - DDM and DDE.

Of the organics identified in sediments, the predominant chemical class (both by numbers of species and in highest concentrations) was the polynuclear aromatic hydrocarbons (PAH's). This group includes chemicals of fairly complex structure whose occurrence in ecosystems in other than low parts per billion levels (ppb) must be attributed to anthropogenic input. PAH's are generally associated with the combustion, use, and handling of fossil fuels. These compounds as a group were the most ubiquitous organics found in Lake Pontchartrain.

TABLE C-13

CONCENTRATIONS OF TOTAL HYDROCARBONS IN SEDIMENT SAMPLES

(ppm wet weight)

Sample Location	3/31/82	6/29/82	9/28/82	1/4/83	4/27/83
LP01		8.4			
LP02	15			13	
LP03		24	100		
LP04		527	1100	1500	
LP05		50			
LP06			91	84	
LP07	50	62	110	100	
LP09	4			9	
LP10	3	6.4	12	12	
LP11	17	21	39	37	
LP12	8.4	3.4	18	18	
LP13	3.3				
LP14	4				
LP15	2		5.5	8	
LP16	2.2	3.6			
SC14			34	20	
SC25			27	32	
NC5 off Goose Point					6.9
NC23 off Mandeville Harbor					5.3
NE5 off Bayou Bonfouca					8.1
NW16 off Pass Manchac					6.3
NW27 off Tchefuncta River					12.3

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-14

Identities and Quantities* of Organic Chemicals of Nonbiogenic Origin in Selected Sediment Samples collected from Lake Pontchartrain, March 31, 1982

	SEDIMENT Station Numbers			
	LP02	LP07	LP11	LP12
° Naphthalene				
alkyl naphthalenes	2	10	7	5
° acenaphthylene				
° acenaphthene		20	2	
biphenyl				
biphenylene				
dibenzofuran				
° fluorene		20	4	3
° diethyl phthalate	8	40	10	10
° phenanthrene	30	230	30	
alkyl phenanthrenes		50	7	
° dibutyl phthalate				
° fluoranthene	120	660	90	50
° pyrene	130	840	120	60
alkyl pyrenes	30	380	40	20
° chrysene isomers	50	450	50	30
alkyl chrysene isomers		50	5	3
° benzopyrene isomers	100	450	90	160
alkyl benzopyrene isomers				
diethylhexyl phthalate				
indole				

TABLE C-14 (Continued)

Identities and Quantities* of Organic Chemicals of Nonbiogenic Origin in Selected Sediment Samples collected from Lake Pontchartrain, March 31, 1982

	SEDIMENT Station Numbers			
	LP02	LP07	LP11	LP12
1-chloro-z-ethoxybenzene				
naphthalenamine or methyl quinoline				
benezenemethanamine, N-(phenylmethyl)				
(1,1'biphenyl)-2 amine				
° polychlorinated biphenyl (PCB)	4	7	5	
DDM				
° DDE	0.6		0.6	0.4
diphenyl methanone				
° diphenyl hydrazine or N-phenyl benzenamine				
9, 10 dihydro -9-9- dimethyl acridine				
trimethyul phenol				
diethyl phenol				
undecylbenzene	25			
dodecylbenzene	70			
tridecylbenzeneisomers	40			
chlorodanee isomers	t	t	t	

* - Concentrations expressed in ng/g wet weight.

° - USEPA Priority Pollutant

t - Less than 1 ng/g.
SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-15

Concentrations of Organic Chemicals, Expressed as ng/g wet weight, in Selected Samples of Sediment Collected June 29, 1982

Sample Location	LP05	LP07	LP01	LP11	LP04
• dichlorobenzene	5	5	4	1	14
tribromoethylene	3	3	2	2	12
• isophorone	28	38	41	28	160
• naphthalene	6	5	3	1	23
alkyl naphthalenes	38	71	44	26	1600
• acenaphthene	5	7	2	1	83
• acenaphthylene		7			26
biphenyl	4	6	5	3	13
alkyl biphenyls	1	2	1		580
• fluorene	6	7	4	1	87
alkyl fluorenes	2	4	5		160
• phenanthrene	41	64	14	7	340
• anthracene	3	13	2	1	120
alkyl phenanthrenes	30	120	45	18	1300
dibenzothiphene	1	7	2	1	80
° Fluoranthene	100	170	34	24	1100

TABLE C-15 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g wet weight, in Selected Samples of Sediment Collected June 29, 1982

	SEDIMENT				
Sample Location	LP05	LP07	LP01	LP11	LP04
° Pyrene	91	160	28	32	940
alkyl pyrenesene	66	200	29	28	960
° benz(a)anthracene	81	130	17	20	650
° chrysene	98	170	28	26	760
alkyl chrysenes	44	73	2	13	270
° naphthobenzothiophene	16	65	5	6	360
alkyl naphthobenzothiophene	7	19			180
° benzo Fluoranthenes	36	49	10	12	170
benzo(e)pyrene	13	12	4	3	40
° benzo(a)pyrene	13	18	3	3	41
peryulene	10	13	19	25	17
° indo(1,2,3-cd)pyrene	3	3	1	1	9
° dibenzo(a,h)anthracene	2	1			9
° benxo (ghi)perylene	5	3	1	1	9
° diethyl phthalate					
° bis(ethylhexyl)phthalate	46	140	8	52	270

TABLE C-15 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g wet weight, in Selected Samples of Sediment Collected June 29, 1982

	SEDIMENT				
Sample Location	LP05	LP07	LP01	LP11	LP04
° Other phthalates					
° DDE	1	1	1	1	25
DDM	2	1	2	1	30
° chlordane	4	4	1	1	84
° nonachlor	1	1	1	1	14
° PCB	1	4	1	1	120
° chloronaphthalene					
° heptachlor					

° USEPA Priority Pollutant

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-16

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected June 29, 1982

Sample Location	LP03	LP04	LP06	LP07	LP10	LP11	LP12	LP15	SC14	SC 25
° naphthalene	6	14	14	3	1	5	3	2	4	4
alkyl naphthalenes	60	830	150	35	5	17	9	6	9	15
° acenaphthene	5	62	10	4	0.3	1	0.4	0.2	0.6	0.6
° acenaphthylene	-	63	24	26	-	-	-	-	-	-
biphenyl	8	18	9	2	1	3	2	0.4	1	1
alkyl biphenyls	40	620	66	18	4	8	5	0.4	5	7
° fluorene	12	98	12	6	0.8	2	1	3	1	1
alkyl fluorenes	32	550	43	13	2	5	3	3	4	4
° phenanthrene	63	360	150	48	4	10	6	3	7	9
° anthracene	12	150	19	16	1	2	1	0.4	1	1
alkyl phenanthrenes	57	770	130	53	6	8	8	4	11	12
dibenzothiphenes	5	42	8	3	0.4	1	1	0.2	1	1
alkyl dibenzothiphenes	29	530	48	22	3	4	3	2	8	5
° fluoranthene	52	660	170	92	7	12	10	3	12	16

TABLE C-16 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected June 29, 1982

Sample Location	LP03	LP04	LP06	LP07	LP10	LP11	LP12	LP15	SC14	SC 25
° pyrene	40	530	140	93	10	13	13	4	18	20
alkyl pyrenes	32	390	87	60	9	9	8	4	10	12
° benz(a)anthracene	34	420	81	73	5	9	7	3	8	11
° chrysene	49	510	130	100	9	14	13	5	13	19
alkyl chrysenes	11	130	25	23	3	4	5	3	4	7
naphthobenzothiophene	6	79	19	11	1	2	1	0.6	2	2
alkyl naphthobenzothiophenes	6	80	13	11	1	3	2	1	2	4
benzo Fluoranthenes	14	200	41	60	7	8	9	4	9	13
benzo(e)pyrene	4	55	11	16	2	2	3	1	3	4
° benzo(a)pyrene	4	75	13	25	1	2	1	1	3	3
perylene	6	8	20	25	29	19	43	35	20	45
° indo(1,2,3-cd)pyrene	0.5	14	2	6	0.4	0.4	0.6	0.5	1	0.4
° dibenzo(a,h)anthracene	0.2	8	1	3	0.1	0.1	0.3	0.3	0.6	0.5
° benzo(ghi)perylene	0.6	19	3	7	0.9	0.6	1	1	1	2
° diethyl phthalate	4	130	36	1	0.5	2	0.3	0.3	2	0.4
° bis(ethylhexyl)phthalate	100	860	50	9	6	7	-	1	5	5
° other phthalates	1	11	-	-	-	-	-	0.2	33	-

TABLE C-16 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected June 29, 1982

Sample Location	LP03	LP04	LP06	LP07	LP10	LP11	LP12	LP15	SC14	SC 25
° DDE	-	1.5	0.5	0.3	0.3	0.1	0.2	0.1	0.1	0.2
DDM	0.4	11	2	0.3	0.8	0.3	0.2	0.1	0.1	0.5
° chlordane	12	170	17	0.3	0.2	0.6	0.2	-	0.2	0.5
° nonachlor	1	8	4	0.2	-	0.1	-	-	-	0.1
° PCB	0.1	-	0.1	1	-	-	0.1	-	-	0.4

° USEPA Priority Pollutant

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-17

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected January 4, 1983

Sample Location	LP02	LP04	LP06	LP07	LP09	LP10	LP11	LP12	SC15	SC14	SC 25
° naphthalene	0.1	4.0	0.6	5.9	0.9	-	-	0.5	0.4	-	0.1
alkyl naphthalenes	1.5	240	9.9	33.	3.2	2.5	3.6	9.9	2.2	2.6	3.3
° acenaphthene	0.2	15	2.8	4.6	0.3	0.2	0.2	0.3	0.1	0.2	0.2
° acenaphthylene	0.04	5.1	2.0	4.4	0.3	0.1	0.3	0.5	0.1	0.3	0.5
biphenyl	--	2.2	1.2	1.4	0.1	-	-	0.2	0.1	-	0.1
alkyl biphenyls	2.7	140	14.	19	1.9	2.0	2.4	4.9	1.4	2.8	3.7
° fluorene	0.7	17	3.5	4.1	0.4	0.4	0.4	0.6	0.2	0.4	0.6
alkyl fluorenes	4.5	140	10.	11.	1.8	1.4	1.6	2.7	1.3	2.5	2.5
° phenanthrene	2.1	110	34.	41.	1.9	3.0	3.3	3.9	1.3	3.5	4.3
° anthracene	0.4	28	4.9	10.	0.7	0.6	0.9	0.6	0.2	0.9	1.1
alkyl phenanthrenes	5.4	270	37.	46.	4.1	4.1	5.5	7.4	2.3	6.8	7.9
dibenzothiphenes	0.2	11.	2.1	2.4	0.2	0.1	0.3	0.4	0.1	0.3	0.3
alkyl dibenzothiphenes	1.2	200	17.	21.	1.7	0.9	3.1	3.2	1.0	3.1	3.0
° fluoranthene	5.5	440	75	110.	5.9	7.1	12.	11.	2.2	14.	17.

TABLE C-17 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected January 4, 1983

Sample Location	LP02	LP04	LP06	LP07	LP09	LP10	LP11	LP12	SC15	SC14	SC 25
° pyrene	3.9	320	58.	91.	6.6	7.8	13.	12.	2.9	19.	16.
alkyl pyrenes	6.6	200	39.	69.	5.5	5.8	7.4	8.5	2.4	12.	11.
° benz(a) anthracene	0.1	260.	59.	99.	4.5	3.8	6.3	6.3	1.5	12.	10.
° chrysene	2.7	260.	53.	90.	5.1	8.3	9.2	9.8	2.7	21.	11.
alkyl chrysenes	4.5	200.	31.	64.	7.6	5.5	9.0	7.6	3.2	13.	11.
naphthobenzothiophene	0.2	36.	6.2	13.	0.6	0.5	1.1	1.1	0.2	1.4	1.3
alkyl naphthobenzothiophenes	0.3	52.	6.6	11.	0.8	0.5	1.9	1.9	0.5	2.0	3.1
° benzo Fluoranthenes	1.4	210	35.	60.	4.5	6.0	6.6	6.8	2.5	9.9	6.7
benzo(e)pyrene	0.5	80.	10.	22.	2.3	1.9	3.1	2.7	1.0	4.3	2.5
° benzo(a)pyrene	0.2	82.	12	23.	1.2	1.1	2.0	1.8	0.4	1.5	1.6
perylene	5.6	37.	22	19.	43.	16.	20.	34.	20.	26.	18.
° indo(1,2,3-cd)pyrene	0.1	35.	4.5	6.0	0.6	0.5	0.6	0.5	0.3	1.1	0.3
° dibenzo(a,h)anthracene	0.3	17.	2.8	2.1	0.3	0.4	0.3	0.3	0.3	0.6	0.4
° benzo(ghi)perylene	0.1	47.	5.0	8.4	1.1	0.9	1.0	1.0	0.3	1.5	0.7
° diethyl phthalate	0.5	110.	2.6	5.7	0.5	0.4	0.5	0.3	1.8	0.7	0.7
° bis(ethylhexyl)phthalate	19.	12.	10.	2.8	1.1	-	13.	9.5	0.3	1.5	17.
° other phthalates	1.0	7.8	5.0	-	0.2	0.1	0.8	0.4	0.1	1.0	3.6

TABLE C-17 (Continued)

Concentrations of Organic Chemicals, Expressed as ng/g Wet Weight,

in Samples of Sediment Collected January 4, 1983

Sample Location	LP02	LP04	LP06	LP07	LP09	LP10	LP11	LP12	SC15	SC14	SC 25
° DDE	-	4.8	0.5	0.3	0.02	-	0.1	0.1	0.03	0.1	0.06
DDM	-	15.	1.1	0.8	0.1	0.2	0.3	0.4	0.08	0.4	0.2
° chlordane	0.1	22.	1.5	1.2	-	-	0.1	0.1	-	0.06	0.2
° nonachlor	-	4.4	0.4	0.4	-	-	0.02	-	-	-	0.06
° PCB	-	2.9	0.6	1.0	-	-	0.1	0.1	0.05	0.05	0.04

° USEPA Priority Pollutant

SOURCE: Louisiana Department of Environmental Quality, 1984.

TABLE C-18

Concentration of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected April 27, 1983

Sample	NC5	NC23	NE5	NW16	NW27
naphthalene	-	0.7	3.7	2.8	1.7
alkyl naphthalenes	1.7	3.2	7.7	7.2	3.1
acenaphthene	0.1	0.2	1.5	0.4	0.2
acenaphthylene	-	-	0.6	-	-
biphenyl	-	0.2	1.2	1.1	0.1
alkyl biphenyls	1.8	0.9	7.2	1.6	0.4
fluorene	0.3	0.3	3.0	0.3	-
alkyl fluorenes	2.7	1.3	5.2	2.3	0.6
phenanthrene	2.5	2.0	13.	2.4	1.2
anthracene	0.5	0.1	2.3	0.5	-
alkyl phenanthrenes	5.3	3.6	18.	7.3	1.6
dibenzothiophenes	0.2	0.2	1.8	0.3	-
alkyl dibenzothiophenes	3.1	1.5	2.9	2.8	0.6
fluoranthene	4.2	5.1	26.	7.3	1.0
pyrene	5.8	6.2	17.	8.1	1.6
alkyl pyrenes	3.4	4.3	11.	6.7	0.4
benz(a)anthracene	-	2.0	2.2	2.1	-
chrysene	4.5	3.8	5.1	4.3	0.5
alkyl chrysenes	1.7	1.4	2.1	2.7	0.2
naphthebenzothiophene	0.5	0.9	1.3	1.6	0.1
alkyl naphthobenzothiophenes	1.3	1.0	1.2	1.4	-
benzofluoranthenes	7.2	8.3	2.3	7.7	0.4
benzo(e)pyrene	2.9	3.4	1.5	2.8	0.2
benzo(a)pyrene	2.4	1.3	0.2	1.5	0.1
perylene	46.	25.	4.4	59.	0.5
indo(1,2,3-cd)pyrene	2.4	2.0	-	0.6	-

TABLE C-18 (Continued)

Concentration of Organic Chemicals, Expressed as ng/g Wet Weight, in Samples of Sediment Collected April 27, 1983

Sample	NC5	NC23	NE5	NW16	NW27
Dibenzo(a,h)-anthracene	1.7	0.8	-	0.6	-
Dibenzo(ghi)perylene	3.6	1.7	-	0.6	-
Diethyl phthalate	0.4	0.4	0.4	0.5	0.4
Bis(2-ethylhexyl) phthalate	1.8	1.2	2.1	1.4	10.
Other phthalates	1.2	0.2	-	-	-
DDE	0.1	0.2	0.1	0.3	-
DDM	-	0.2	-	0.2	-
Chlordane	-	-	-	-	-
nonahclor	-	-	-	-	-
PCB	-	1.3	-	-	-

SOURCE: Louisiana Department of Environmental Quality, 1984.

Mean PAH levels indicate that the station near the 17th Street Canal (LP04) has the highest concentrations of PAH's, approximately 2.9 ppm. This is not representative of the lake. Mean PAH concentrations at LP04 are about three times higher than the next highest nearshore station (LP07) and about five times higher than the overall nearshore mean concentration (without LP04). Levels at LP04 are about 19 times higher than the intermediate station levels where the mean concentration is 158 ppb. The offshore and northern average of 72 ppb is about 1/40 of the concentration at LP04.

The most important man-induced sources of petroleum entering the environment are those associated with waterborne transportation (losses during ship operations, oil spills at sea, and oil spills during terminal operations) and surface runoff.

Aromatic hydrocarbons, in particular PAH's, may enter the aquatic environment from sources other than petroleum. A major source of PAH's in the environment is the combustion of organic materials including fossil fuels. PAH's may even be derived from particulates formed during natural fires. Municipal incinerators also produce PAH's, which may be released to the environment in wastewater. High levels of aromatic hydrocarbons are often indicators of petroleum pollution.

Several PAH's were detected in the tissues of oysters from the vicinity of Norfolk, Virginia; similar results were obtained with oysters from several polluted and unpolluted stations in Galveston Bay and from relatively unpolluted Aransas Bay, Texas. The presence of pollutant hydrocarbons in the tissues of populations of marine animals suggest that these organisms can accumulate hydrocarbons from the water, food, and sediments.

Bioassay studies performed on the clam Rangia cuneata to determine the accumulation and release of hydrocarbons from sediment and food indicated that clams in direct contact with contaminated sediment contained

no more napthalene than those suspended in the water column, indicating uptake from the water, but not from the sediment. Additional tests indicate that molluscs may have a limited ability to accumulate hydrocarbons directly from heavily contaminated sediment. Uptake efficiency from the water column is much greater.

The most important hydrocarbons from a general toxicological standpoint are the aliphatics, aromatics, and phenols; however, their toxicity may be mitigated in aquatic systems. The phenols contribute little to sediment contamination because they are readily metabolized and are relatively water soluble. If aliphatics are present in sediment in high enough quantities, they could pose a problem, although they would end up as tarballs and not cause direct toxicity to organisms. The higher molecular weight PAH's are acutely toxic only at concentrations approaching saturation. Important chronic effects occur at much lower levels; low levels of PAH's can alter or inhibit development of embryos in aquatic organisms. Also, PAH's have been implicated in the production of cancer in fish both in the field and in the laboratory.

Findings of six studies conducted under the Dredge Material Research Program dealing with the effects of contaminants on aquatic organisms revealed the following: uptake of sediment-associated heavy metals by organisms was rare, bulk analysis of sediments for metals did not reflect their potential environmental impact, and oil and grease residues were tightly bound to sediment making them unavailable for uptake by organisms.

Another fairly ubiquitous group of organics were the phthalate esters. Identifications of four different phthalates were confirmed for Lake Pontchartrain samples. These chemicals are plasticizers that have many uses in chemical manufacturing. Their occurrence in the lake is undoubtedly associated with diffuse sources on the urban south shore area. Concentration in sediments ranged from a few parts per billion to as high as 360 ppb (Station LP04). Nearshore areas typically exhibited

markedly higher levels than offshore where concentrations rarely exceeded 2 ppb. Intermediate stations (less than two miles from shore) ranged up to levels of 10 ppb. Levels in nearshore areas along Orleans Parish were higher than along Jefferson Parish.

Four identified compounds of the fairly large class of halogenated volatile and aromatic hydrocarbons were quantified in lake samples. These included compounds such as dichlorobenzene, chloronaphthalene, and tribromoethylene. They were detected only very sporadically in the area off Orleans Parish. Their concentrations ranged from 1-20 ppb in sediments.

An important group of organic chemicals detected were the synthetic chlorinated hydrocarbon pesticides and polychlorinated biphenyls (PCB's). This group potentially represents the greatest threat to any aquatic ecosystem. They are strictly synthetic chemicals that can exert toxic effects at relatively low levels of exposure to aquatic organisms. The synthetic chemicals detected in Lake Pontchartrain included only the six listed earlier. Overall, PCB concentrations were higher than those of any other synthetic chlorinated hydrocarbons in Lake Pontchartrain sediments; however, with the prominent exception of station LP04, levels at all other localities were fairly low. Mean concentrations of PCB's, chlordanes (chlordane plus nonachlor), and DDT metabolites were more than an order of magnitude higher at LP04 than the next highest mean concentrations at the other locations (LP07 for PCB's, LP06 for chlordanes, and LP05 for DDM/DDE). Station LP04 (near the 17th Street Canal) must be considered an outlier and is not representative of the lake, or even of the other nearshore stations.

Mean concentration for chlordanes decreased progressively with distance from the south shore. Excluding Station LP04 as an obviously contaminated outlier, the mean concentrations for all other nearshore stations combined was 5.1 ppb. From this level, a nearly ten-fold decrease in mean concentration (0.6 ppb) occurred by the distance from

the south shore of the intermediate stations (1.0 to 1.8 miles). A further ten-fold decrease in combined mean concentration (0.06 ppb) was obtained by the distance of the southern offshore stations (2.75 to 4.5 miles).

A somewhat similar but less dramatic pattern was evident for the DDT metabolites. From a combined mean concentration of 1.0 ppb at the near-shore stations (again excluding LP04), a five-fold decrease to 0.2 ppb was reached by the distance of the intermediate stations; but no further significant decrease occurred at the offshore stations (0.18 ppb). PCB's show a less dramatic decrease in mean concentrations (LP04 again excluded) from nearshore stations (1.4 ppb) to intermediate stations (0.9 ppb). However, from intermediate station distances to the offshore stations, a near ten-fold decrease to 0.1 ppb was obtained. Comparison with mean concentrations of these compounds from stations in the northern part of the lake indicates input from the North Shore to be less than that from the south shore. Chemical analyses of sediments collected in Lake Maurepas at the locations shown on Figure D-10 are presented in Tables C-19 through C-23. No statistical differences were observed between sites for any of the parameters on a consistent basis.

The Corps of Engineers collected water and sediment samples in the northern part of Lake Pontchartrain in June 1985. Samples were collected in and near the bar channels of Bayou Bonfouca, Bayou Lacombe, the Tchefuncte River, and the Tangipahoa River. Three water and sediment samples were taken from each bar channel and three sediment samples from each nearby dredge disposal area. The locations of these samples are as follows:

Bayou Bonfouca Bar Channel -
BB1-A - Mouth of Bayou Bonfouca
BB2-A - 5,000' south of mouth of Bayou Bonfouca
BB3-A - 9,000' south of mouth of Bayou Bonfouca
BB1-B - 2,000' southwest of BB1-A
BB2-B - 1,500' west of BB2-A
BB3-B - 1,500' west of BB3-A

TABLE C-19

SEDIMENT CHEMISTRY (SEPTEMBER 1983)*

PARAMETERS	STATIONS 1	2	3	4	5	6	7
NH_3	3.61	4.70	5.38	5.76	3.71	4.54	5.28
NO_3	1.91	1.41	1.34	1.64	1.54	2.03	0.74
NO_2	0	0	0	0	0	0	0
TKN	731.0	814.0	937.0	1245.0	601.0	829.0	922.0
TP	260.0	259.0	374.0	742.0	810.0	220.0	242.0
OPO_4	0.84	0.98	1.04	0.86	0.90	1.38	0.87
Si	87	86	11	11	95	92	89
SO_4	--	--	--	--	--	--	--
Cl	41	40	6	116	54	144	208
Dry Weight	276	303	387	618	537	333	285

* All reported values are mg/kg except for dry weights which are mg/g.

SOURCE: Childers (1985)

TABLE C-20

SEDIMENT CHEMISTRY (DECEMBER 1983)*

PARAMETERS	STATIONS						
	1	2	3	4	5	6	7
NH_3	0.20	0.41	0.86	0	0.54	0.09	2.79
NO_3	0.08	0.13	0.01	0.10	0.13	0.09	0.11
NO_2	3.76	3.56	1.99	2.03	2.94	0.96	0.14
TKN	680.0	735.0	758.0	833.0	675.0	735.0	645.0
TP	198.0	210.0	274.0	395.0	151.0	126.0	160.0
OPO_4	0.91	0.51	1.35	1.51	0.24	0.27	0.25
Si	24	35	29	31	23	24	33
SO_4	75	85	65	110	90	90	120
Cl	129	55	119	84	130	187	150
Dry Weight	278	352	334	487	518	305	244

*All reported values are mg/kg except for dry weights which are mg/g.

SOURCE: Childers (1985)

TABLE C-21

SEDIMENT CHEMISTRY (MARCH 1984)*

PARAMETERS	STATIONS 1	2	3	4	5	6	7
NH_3	6.07	3.97	5.89	5.60	3.62	5.90	7.25
NO_3	1.64	1.69	2.13	1.95	2.93	3.97	1.91
NO_2	0.19	0.20	0.18	0.25	0.17	0.14	0.24
TKN	158.8	355.0	235.0	777.0	579.6	514.0	468.0
TP	42.0	121.6	104.2	362.0	220.8	167.2	140.8
OPO_4	1.08	1.08	0.95	1.83	1.18	0.43	0.99
Si	21	24	34	28	54	28	34
SO_4	36	20	25	21	47	31	38
Cl	101	24	42	32	61	120	139
Dry Weight	312	346	376	571	531	368	342

*All reported values are in mg/kg except for dry weights which are mg/g.

SOURCE: Childers (1985)

TABLE C-22

SEDIMENT CHEMISTRY (JUNE 1984)*

PARAMETERS	STATIONS						
	1	2	3	4	5	6	7
NH_3	2.72	4.02	2.71	0.69	3.36	3.74	5.89
NO_3	3.29	3.10	3.58	2.41	2.09	1.45	1.96
NO_2	0.18	0.15	0.15	0.14	0.18	0.16	0.12
TKN	639.0	575.0	524.0	606.0	610.0	627.0	762.0
TP	246.0	196.0	357.0	282.0	238.0	189.0	202.0
OPO_4	1.18	0.51	0.61	0.75	1.53	0.44	0.44
Si	18	19	21	12	18	20	24
SO_4	101	75	72	58	81	60	61
Cl	432	203	261	241	380	310	236
Dry Weight	276	466	416	576	591	388	326

*All reported values are in mg/kg except for dry weights which are mg/g.

SOURCE: Childers (1985)

TABLE C-23

SEDIMENT CHEMISTRY (SEPTEMBER 1984)*

PARAMETERS	STATIONS						
	1	2	3	4	5	6	7
NH_3	2.34	1.74	5.68	4.05	3.30	3.86	6.07
NO_3	6.97	2.14	1.95	2.76	3.29	2.70	2.02
NO_2	0.18	0.33	0.21	0.13	0.17	0.11	0.10
TKN	732.0	744.0	861.0	774.0	825.0	590.0	864.0
TP	262.0	233.0	362.0	328.0	300.0	206.0	254.0
OPO_4	2.78	2.03	2.93	1.20	2.25	0.60	0.57
Si	54	50	56	53	48	53	53
SO_4	115	118	86	88	151	69	47
Cl	296	53	117	135	693	234	173
Dry Weight	293	558	349	381	591	359	321

*All reported values are in mg/kg except for dry weights which are mg/g.

SOURCE: Childers (1985)

Bayou Lacombe Bar Channel -

BL1-A - Mouth of Bayou Lacombe

BL2-A - 3,000' southwest of mouth of Bayou Lacombe

BL3-A - 5,500' southwest of mouth of Bayou Lacombe

BL1-B - 1,500' northwest of BL1-A

BL2-B - 1,500' northwest of BL2-A

BL3-B - 1,500' northwest of BL3-A

Tchefuncte River Bar Channel -

TR1-A - Mouth of Tchefuncte River

TR2-A - 1,000' southwest of Range Front Light No. 5820

TR3-A - 4,000' southwest of Range Front Light No. 5820

TR1-B - 1,200' northwest of TR1-A

TR2-B - 1,800' north of TR2-A

TR3-B - 1,300' northwest of TR3-A

Tangipahoa River Bar Channel -

TAN1-A - Mouth of Tangipahoa River at Light No. 8

TAN2-A - 3,000' southeast of Light No. 8

TAN3-A - 6,400' southeast of Light No. 8

TAN1-B - 1,500' west of TAN2-A

TAN2-B - 1,500' south of TAN2-A

TAN3-B - 1,200' southwest of TAN3-A

Elutriates were performed with sediment and water samples from each bar channel. The elutriate test is a simplified simulation of the dredging and disposal process, wherein predetermined amounts of dredging site water and sediment are mixed together to approximate a dredged material slurry. It is a conservative estimate of contaminant release caused by the dredging process. The samples were analyzed for selected metals and nutrients as well as 37 selected organic compounds.

In the following discussion, the nomenclature is shown below. Samples have been coded as follows: Loc1-Site-Loc2-Type

Where:

Loc1 = BB, BL, TAN, or TR representing Bayou Bonfouca, Bayou Lacombe, Tangipahoa River, and Tchefuncte River, respectively.

Site = the site number of the sampling in the Loc1 area.

Loc2 = A, or B specifying the dredge and disposal areas, respectively.

Type = T, D, E, or S indicating the total (raw), dissolved, elutriate, and sediment sample forms, respectively.

COMPARISON OF WATER AND ELUTRIATE CONSTITUENTS WITH EPA CRITERIA

All ammonia concentrations in the water samples are within the EPA acute and chronic criteria. Ammonia in all the elutriates is within the acute criteria. However, except for samples BB-1-A-E, BB-3-A-E, BL-3-A-E, and TR-3-A-E, all elutriate ammonia concentrations exceed the chronic criterion for sensitive species absent which is applicable in this area. These observations were made assuming a temperature of 30°C and a pH of about 7. The concentrations are much below the acute criteria and are not cause for alarm. Dredging is a temporary process and dilution with the surrounding water takes place. It is normal for ammonia to be released when dredging sediment with a high organic content.

Arsenic and cadmium concentrations in all the water and elutriate samples are less than the applicable EPA criteria.

The total chromium concentrations in TAN-2-A-T, TAN-3-A-T, and TR-1-A-T exceed the criteria for chromium VI but are well within the criteria for chromium III. It is not possible to determine the concentration of each type of chromium from the total chromium analysis. However, chromium III is much more common than chromium VI.

Lead concentrations in all of the water and elutriate samples are below the EPA acute criterion. However, the chronic criterion is exceeded in samples BB-1-A-T, BB-2-A-T, BB-3-A-T, BB-3-A-D, BB-3-A-E, BL-1-A-T, TAN-1-A-T, TAN-2-A-T, TAN-3-A-T, TR-1-A-T, TR-2-A-T, and TR-3-A-T. Only one of these samples is an elutriate, indicating that the lead would be adsorbed to the sediments during the dredging process, therefore reducing the lead concentrations in the water column.

Mercury concentrations in all of the water and elutriate samples are below the EPA acute criterion. The chronic criterion is exceeded in samples BB-1-A-T, BB-1-A-D, BB-2-A-D, BB-2-A-E, BB-3-A-T, BB-3-A-D, BB-3-A-E, BL-1-A-D, BL-2-A-D, BL-3-A-T, BL-3-A-D, BL-3-A-E, TAN-3-A-T, and TR-3-A-T. Mercury was undetected in all other samples. However, the detection limits are above the chronic criterion. Only three of these samples are elutriates. Shell dredging is a temporary operation at any one location. Therefore, the slightly elevated levels of mercury indicated by the three elutriates are not cause for concern. The acute criterion is more applicable in this case.

All zinc concentrations in the water and elutriate samples are below detection limits. However, the detection limits are above the criteria.

Nickel concentrations in all the water and elutriate samples are less than the applicable EPA criteria.

In the water and elutriate samples, all organic compounds, including PCP, were below detection limits with the exception of DDE. DDE was detected in water samples BB-1-A, BB-2-A, and BB-3-A. The concentrations are less than 0.1 PPB, which is well below the EPA criterion of 1050 PPB.

SEDIMENT CONCENTRATIONS

All sediment concentrations with the exception of arsenic and zinc are within the "EPA Proposed Criteria for Determining Acceptability of Dredged Sediments Disposed in EPA Region VI." The arsenic criterion is exceeded in samples TAN-1-A-S, TAN-3-B-S, and TR-1-A-S. The zinc criterion is exceeded in samples TR-1-B-S and TR-2-B-S. Although the levels of arsenic and zinc in these samples exceed the criteria, they are much lower than the "EPA "Alert" Levels for Bottom Sediment Constituent Concentrations." All organics were below detection limits.

COMPARISON OF ELUTRIATE CONCENTRATIONS WITH AMBIENT WATER CONCENTRATIONS

Ammonia concentrations in all the elutriate samples are significantly higher than in their respective ambient water samples. The significance of these concentrations was discussed previously under "Comparison of Water and Elutriate Constituents with EPA Criteria."

The lead concentration in BB-3-A-E is significantly higher than in BB-3-A-D, although both concentrations exceed EPA's chronic criterion but not the acute criterion. All other lead concentrations as well as cadmium, chromium, and mercury concentrations in the elutriates are generally lower than in their respective dissolved water concentrations.

Nickel concentrations in the elutriates are generally higher than in their respective water samples. The concentrations of phosphate at all locations except Bb-1-A are higher in the elutriates. This is to be expected when dredging material with a higher organic content and is not a problem at these concentrations.

Sediments - Physical Characteristics

The bottom sediments in most of the permitted area of Lake Pontchartrain are predominantly clays and silts having moderate to high

organic content. This reflects the recent geomorphic history of the area, which has favored the deposition and retention of alluvial sediments in the gently sloping central basin, which is only indirectly connected to the Gulf of Mexico. Only the shallower nearshore portions of the lake and its eastern arm near the tidal passes contain appreciable coarse sediment fractions. Bonnet Carre' Spillway operations during Mississippi River floods have permitted continued the periodic deposition of organically rich silt and clay in the west-southwestern portion of the lake that formerly occurred when major floods crevassed the weaker pre-modern levees in that reach of the river.

The shallow depths of Lake Pontchartrain, generally 15 feet or less, and the small tide ranges promote the dominance of wind driven circulation patterns. Wind speeds of 15 miles per hour are able to begin resuspension of bottom sediments, except in the deeper eastern portions of the lake. At speeds of 40 miles per hour, complete resuspension of unconsolidated bottom sediments occurs throughout most of the lake. These wind speeds are exceeded on the average about 15 and 1 percent of the time. The bottom currents associated with tides are generally too slow to cause resuspension, but can keep the sediments in motion once they are resuspended by other means, e.g. wind-induced turbulence, shell dredging, and shrimp trawling.

The purpose of this discussion is to present pertinent information about sediment behavior and conditions in the water column and bottom of Lake Pontchartrain with regard to the shell dredging issue, and to present conclusions about the physical impacts of clam shell dredging on the sediment regime of the lake. Discussions in this section are generally confined to the portions of Lake Pontchartrain which have been open to shell dredging in recent years. Accordingly, discussion of Lake Maurepas, which has been closed to shell dredging since 1984, is limited to a brief review of information and events pertaining to dredging activity in 1983 and 1984.

Turbidity is the optical property of water that causes light to be scattered and absorbed rather than be freely transmitted. The scattering and absorption are caused by dissolved and suspended substances in the water, and are most directly related to suspended solids concentration, but also to sediment particle shape and size distribution, refractive index, color, and absorption spectra (Wechsler and Cogley, 1977). Turbidity may be expressed in various units, depending on the method of measurement. Most turbidimeters in current use measure turbidity in terms of light transmission (transmissometers) or light scattering (nephelometers). Secchi discs are also widely used to measure depth of light penetration from the surface.

Suttkus et al. (1954) measured light penetration depths at many Lake Pontchartrain sites from 1953 to 1955. From November to April, Secchi depths ranged from about 60 to 130 cm, or about two to four feet. During the warmer months, depths in excess of five feet were commonly measured. Since the 1970's, lakewide turbidity levels have been significantly higher (Secchi depths significantly shallower) than had been observed by Suttkus. At least a part of the general increase has been attributed to four Bonnet Carre' Spillway operations since 1973 and to higher tributary discharges during the same period. During the 1974-1981 period, Amite River discharges averaged 17 percent higher than the longer-term discharges of 1939-1981. Pearl River discharges averaged 33 percent higher during the same more recent period. The immediate effects on the lake turbidity of sediment-laden inflows have probably been supplemented by the residual effects of increased amounts of loosely consolidated fine-grained sediments available for resuspension by waves, shell dredging, and trawling.

It has been observed during open-water dredging and disposal activities that suspended sediment concentrations become greatly elevated in the immediate vicinity of the dredge intake (fishmouth in the case of shell dredges) and the discharge pipe. Turbidity plumes are caused by clay and silt particles smaller than .03 mm and flocs (masses) of

agglomerated particles that settle very slowly in the water column. Field investigations of Lake Pontchartrain shell dredging operations in 1974 and 1984 showed that suspended sediment concentration in mg/L and in NTU's (Nephelometric Turbidity Units) were elevated to several hundred units near the dredge at the water surface. Corresponding near-bottom values were usually several times higher than the surface levels.

The shell dredges active in Lake Pontchartrain are fishmouth suction dredges that operate by pushing or pulling the suction scoop through the sediments at a depth of about 2 to 3 feet below the original bottom elevation. The pumped slurry of soil and shells passes through process equipment on the dredge which separates the larger shells and shell fragments from the mixture. The separation process consists of screening, sorting, and washing, followed by removal of the retained shell to a nearby barge for temporary storage and subsequent transport from the site. The remaining mixture of soil, water, and shell drains by gravity through one or two main discharge pipes at the stern of the dredge back into the water column.

The operational factors most pertinent to turbidity plume generation by a shell dredge are the dredged slurry solids concentration, the slurry discharge rate, the discharge pipe configuration, and the propeller configuration relative to the discharge pipe. Steimle and Associates, Inc. (1985) performed an engineering study for Louisiana Materials Company. They measured the intensity, duration, and areal extent of the turbidity plumes of two operating dredges, and also investigated the feasibility of altered discharge configuration and other turbidity-reducing techniques. Based on the study results, Steimle and Associates recommended certain discharge pipe changes, including the connection of the two discharge pipes on the dredge A. W. Shucks and extending the main discharge to a level below the propeller shaft centerline. For the other dredge, the Chickasaw, it was recommended that its horizontal discharge (above the waterline) be changed to a downward-directed discharge below the propeller line as for the A. W. Shucks dredge.

One of the major tasks of the Dredged Material Research Program (DMRP) directed by the U.S. Army Corps of Engineers Waterways Experiment Station, was to develop a predictive capability for the nature, degree, and extent of dredged material dispersion at dredging and open-water disposal sites. A series of reports were published in 1977 and 1978 describing the research results. Although the investigations were associated primarily with hydraulic pipeline and hopper disposal of navigation channel dredged material, the relationships derived can be applied generally to Lake Pontchartrain shell dredging operations. In each case, it was observed that upper water column turbidity decreased quickly with distance away from the disposal site as the result of vertical settling and horizontal dispersion. Depending on the percentage of fine-grained material in the discharge, only about 1 to 3 percent of the discharged solids remains in suspension long enough to contribute to upper water column turbidity (Nichols et al., 1978). The remaining material descends rapidly toward the bottom where it forms a low to medium-density fluid mud mound. Sediment concentrations at the water-fluid mud interface are typically about 10 g/L, and gradually increase to levels of 300 to 500 g/L at the bottom of the deposited layer.

The research program demonstrated that material dispersion at discharge sites can be best controlled by using various discharge configurations such as vertically-directed and submerged pipes (Barnard, 1978). Optimal turbidity control could be obtained by a submerged diffuser system at the end of the discharge pipe, but this adaptation would not be economically practicable for the Lake Pontchartrain shell dredges. Silt curtains are under certain circumstances effective and practical devices for turbidity control, but not in the case of the shell dredges, which continuously move, requiring a minimum enclosed surface area of a fixed silt curtain of about 2.0 to 2.5 miles in diameter (Steimle and Associates, 1985).

A laboratory study of turbidity generation potential of clay and natural sediments was performed by the Walden Division of Abcor, Inc. for the DMRP (Wechsler and Cogley, 1977). Turbidity was monitored as a function of time in waters of various salinity, hardness, and pH levels. Statistical analyses of the data were conducted to evaluate the relative importance of sediment properties and water composition to settling rates of the suspended materials. Turbidity was measured in terms of percent light transmission, light scattering, and suspended solids.

A single linear regression equation was determined to be statistically significant at the 1 percent level between the light attenuation coefficient and suspended solids concentration for both the clays and the natural sediments from eight dredging sites. The determination coefficient, r2, of 0.84 meant that 84 percent of the variance in light transmission was explained by the suspended solids concentration. Somewhat poorer correlations were obtained when comparing the degree of light scattering with suspended solids (r2 values of 0.72 and 0.60 for the clays and the natural sediments, respectively). It is important to establish such relationships so that field and/or laboratory measurements of turbidity may be appropriately used to approximate suspended sediment concentrations, which are less easily measured than the light transmission or scattering properties of the water column.

The turbidity vs. time relationships for three common clay minerals, kaolinite, illite, and montmorillonite in fresh waters showed persistent high turbidity (low settling rates) for each mineral in soft water, but significantly faster turbidity reduction in hard water (200 mg/L total hardness). The montmorillonite samples and clay mixtures containing montmorillonite all experienced much more rapid turbidity reductions than the other clay samples in hard water. Solutions containing as little as 0.1 percent sea salt, i.e., 1.0 part per thousand (ppt) total salinity, induced greatly accelerated turbidity reductions compared to the fresh water, particularly for the samples containing montmorillonite.

The process of flocculation, i.e., the mutual adherence of clay particles to produce relatively large agglomerates that attain significant settling velocities, is induced by the presence of calcium and magnesium ions (hardness), or by sodium and other positive ions occurring in estuarine waters. The primary negative charges on the clay particle surfaces cause mutual repulsion of the particles in water unless or until enough positive ions are present to reduce the strength of the electrical fields, allowing the particles to come together (coagulate) and begin to settle. Once flocculation is induced, the montmorillonite appears to interact with the other clays by coagulating them or "sweeping out" other particles during settling.

Salinity levels greater than 5 ppt were found to have little additional influence on montmorillonite flocculation and settling. Nor were the settling rate differences between 1.0 and 5.0 ppt salinity solutions as great as between those samples which did or did not contain montmorillonite. Although pH appeared as a significant influencing variable in the regression analyses, it was concluded that this occurred because the salty and hard waters were always basic in the tests, and that the pH factor actually reflected the salinity and hardness effects. A limited number of tests made with low concentrations of silt, which does not tend to flocculate, showed little effect on the observed turbidity reduction rates attributable to clays, indicating little or no interaction between clay and silt.

The eight natural sediments tested included four each from freshwater and estuarine dredging sites. The Mobile Bay sediment was probably most similar to those sediments encountered in the permitted areas for Lake Pontchartrain shell dredging with regard to moisture content, organic carbon content, and particle size, although it was somewhat coarser than the silty clays most prevalent in the shell dredging areas of Lake Pontchartrain. Comparative tests of the natural sediments were made to relate differences in settling behavior to sediment composition characteristics at 1,000 mg/L initial concentration in 1.0 ppt salt

solutions, both in terms of absolute turbidity values and after normalization to the initial turbidity.

The organic content was found to be the predominant compositional factor affecting natural sediment settling rates, with higher organic levels responsible for more rapid turbidity reduction. The proportion of montmorillonite to other clay minerals was found, however, to be an unimportant factor for the natural sediments. Two possible explanations were suggested for this, the first being that the overwhelming importance of organic carbon in affecting settling behavior tends to mask the clay mineral properties. The second possibility is that the particular montmorillonite sample that was tested may have behaved as it did not only because of its mineralogy, but perhaps also because of its much finer particle size or some other factor. Regardless, the tests showed that clay mineralogy is less important in the settling behavior of natural sediments than other factors.

Initial sediment concentrations also were an important factor, with the higher initial concentrations leading to more rapid turbidity reduction. This may have been due to more frequent particle collisions, or to increased organic matter concentrations, or both in the more concentrated sediments. Although the silts generally settled independently as expected, it was found that significant differential settling of the various clay sizes did not occur. This also suggested the important role of organics in promoting complex aggregate formations of clay and organic matter after induced flocculation by water hardness or salinity.

The analytical results were used to develop a turbidity plume computer model which yielded favorable comparisons with available field data in Mobile Bay. The research conducted with the eight natural sediments showed that turbidity plumes are largely predictable from knowledge of sediment properties, but that hydrodynamic factors controlled by winds and tides are nevertheless important. Dredge movement with respect to prevailing currents is also an important determinant of turbidity

dispersion characteristics. Other factors, including turbulent mixing in the discharge pipe and homogeneity of the discharged material may also be important factors in turbidity generation and reduction.

Schubel *et al.* (1978) developed a relatively simple method for predicting turbidity plume characteristics based on a theoretical hydraulic model. This plume model has been verified and refined using field data collected at three open-water pipeline disposal operations in estuaries. The input parameters are dredge discharge rate, water depth, average current velocity, mean particle diameter or settling velocity, an estimate of diffusion velocity, and the age of the plume, which is dependent on the tidal type (diurnal or semi-diurnal) and/or longitudinal current velocity in the case of a river.

Given these six parameters, ratios and scaling factors can be developed and applied to a series of nomographs to estimate vertically-averaged suspended solids concentrations along the plume centerline with respect to distance from the discharge location. After dredged material discharge ceases, the suspended material will settle and disperse laterally, with the visual near-surface plume usually disappearing after one to two hours (Nichols *et al.*, 1978). Depending on depth settling velocity and diffusion velocity, the subsurface plume may persist considerably longer. Schubel *et al.* (1978) also gives a method for estimating plume concentration decrease with time as a function of settling and/or diffusion.

The referenced turbidity plume model was applied to known and/or estimated data and conditions at a shell dredge field investigation conducted in Lake Pontchartrain in December 1984 (Steimle and Associates, 1985). The model gave an average water column suspended solids concentration (above background) of 11 mg/L at the distance to maximum width of plume (2.0 miles). At distances of 0.15, 0.78, and 1.80 miles from the discharge location, the predicted depth-averaged plume centerline concentrations were 2,000, 240 and 55 mg/L above background.

Field samples of turbidity and total suspended solids concentrations (TSS) were taken at five stations on a transect that crossed the path of the dredge A. W. Shucks. Samples were taken at time intervals after passage of the dredge. The observed TSS values at corresponding distances of 0.15, 0.78, and 1.80 miles from the dredge were 310, 110 and 89 mg/L.

The plume model-predicted TSS concentrations were much higher for the shorter distances. Some of the discrepancy might have been due to an inaccurate mean particle size estimate of .006 mm for this location, representing the average of four sediment samples taken in the southwestern part of the lake in 1974. If the true mean size were significantly greater, this would result in more rapid early settling and a flatter (more uniform) concentration gradient along the plume centerline, as the observations indicated. Other estimated factors whose errors could have materially affected model results include percent of discharged solids contributing to the turbidity plume and the horizontal diffusion velocity. The weather conditions during the field investigation were calm, so unusual hydrodynamic conditions should not have been a factor. It is not certain, however, whether the field measurement method truly compensated for the continuous movement of the dredge at a speed of about two miles per hour, i.e., equated the plume conditions to what would have been observed at the same distances from a stationary discharge. The plume model is not capable of providing for particular wind and wave conditions or a moving discharge.

At this time, there are no known sets of dredge discharge condition data including solids content of the slurry, comprehensive water column turbidity plume measurements, and corresponding settling velocity determinations of bottom sediments available from the Lake Pontchartrain study area to verify an existing predictive model. Nor are either of the referenced plume models presently capable of simulating a moving discharge source, or correcting for wind-induced turbulence.

Field surveys of turbidity plumes from shell dredges in Lake Pontchartrain were conducted in May and August 1974 by Gulf South Research Institute (GSRI), in May and November 1983 by the Louisiana Department of Natural Resources (DNR), in September 1984 by the Louisiana Department of Environmental Quality (DEQ), and by Steimle and Associates, Inc., in August and December 1984. GSRI monitored three dredged areas and control sites in west central, south central, and southwestern Lake Pontchartrain. Turbidity, TSS, and a broad range of other water quality parameters were measured near the surface and bottom of the water column. Turbidity and suspended solids were sampled at distances of 50 to 2,200 feet from the operating dredge Kathy L. along radials extending outward from the center of the dredged circle at 60-degree intervals.

Maximum top and bottom TSS values of 1,890 and 5,640 mg/L were measured at distances of 50 and 400 feet from the dredged circle. This method of measurement would be less likely to include the plume centerline the greater the distance from the dredge, so the more distant maximum reported bottom TSS and turbidity values are more likely in greater disagreement with the true maximum values. The maximum turbidity levels recorded were 410 JTU's at 50 feet (surface) and 3,000 JTU's at several distances (bottom). The covariations of the tabulated turbidity and TSS values at distances along the radials were somewhat inconsistent, however, introducing some doubt about the relationship between the two parameters and/or of the accuracy of some of the measurements. Control site TSS values averaged 53 and 69 mg/L, respectively.

The complex physical processes involved and the limited available data preclude a definitive analysis of these and other shell dredging data in terms of each of the important contributing factors to turbidity plume generation. Sediment samples were taken in the vicinity of the GSRI dredge cut survey sites. Mean particle sizes ranged from about 3 to 11 u (.003 to .011 mm), so some differences in settling characteristics during a particular dredging survey would not have been unexpected.

The May 1983 DNR investigation utilized three sampling boats which collected water samples before and after the passage of an operating dredge, and a fourth boat which sampled immediately behind the dredge. The reported near-dredge turbidity levels were 270 NTU's (surface) and 1,120 NTU's (bottom). Corresponding TSS values were 410 and 2,280 mg/L, respectively. The background surface and bottom turbidity levels each averaged 19 NTU's.

A DNR investigation of shell dredge activity was conducted in November 1983 in southeastern Lake Pontchartrain, but was aborted after about 4.5 hours because of high winds and waves. Maximum measured surface and bottom turbidity values of 800 and 1,000 NTU's were recorded at a station immediately behind the dredge Sheldrake after one hour of observations. Corresponding maximum measured TSS values were 800 and 1,300 mg/L. It is not known whether these values were actually the highest that occurred in the generated plume. Background surface and bottom turbidity averaged 35 and 58 NTU's, respectively.

In May 1984, DEQ monitored turbidity levels and other water quality parameters near an operating shell dredge in southeastern Lake Pontchartrain. The turbidity plume was sampled at a stationary site periodically from 30 minutes before to 6 hours after the passage of a shell dredge at time zero. Surface turbidity quickly rose from an ambient level of 6 NTU's to 2,520 NTU's as the dredge passed the site. At 30 minutes after time zero, the surface turbidity had decreased to 30 NTU's, and further decreased to a stabilized value of 10 NTU's. The bottom turbidity levels rose from 13 NTU's (background) to 6,000 NTU's as the dredge passed, but the maximum bottom turbidity observed (at 30-min intervals) was 11,600 NTU's at one hour after dredge passage. Subsequent samples at 1.5, 3, and 6 hours after time zero measured 800, 99, and 30 NTU's, respectively. Thus, the bottom turbidity was still slightly elevated five hours after the surface plume had stabilized. This investigation, though more revealing of the temporal behavior of a shell dredging plume than the others cited above, represents a single set of

conditions and should not be considered as other than a general indicator of plume behavior.

In July 1984, turbidity generated by the dredge A. W. Shucks in central Lake Pontchartrain was monitored by Steimle and Associates, Inc. Samples at distances one-half mile or greater from the dredge revealed a maximum surface turbidity of 46 NTU's and a maximum bottom turbidity of 507 NTU's. Similar measurements at one-fourth mile or more from the dredge Chickasaw the same day in the central part of the lake showed maximum observed surface and bottom levels of 96 and 1,540 NTU's, respectively. These samples were too far removed from the dredge to reveal much about the maximum near-dredge levels, even if extrapolated to shorter distances.

The above-named dredges, with 38,500 gallon per minute (gpm) discharge capacities, and the Avocet, with a 32,000 gpm capacity, were monitored in southwestern Lake Pontchartrain for turbidity and TSS in December 1984. Maximum observed surface turbidity levels were 113, 62, and 42 NTU's, and the maximum bottom values were 120, 330, and 420 NTU's. Corresponding maximum observed TSS concentrations were: surface - 247, 382 and 117 mg/L, and bottom - 368, 720, and 1,870 mg/L. All of the maximum surface and bottom values were recorded at distances of 0.15, 0.45, and 0.00 mile from the sites of dredge passage over the transect, which were the minimum distances that were sampled. Elapsed times from dredge passage were 5, 15, and 0 minutes.

The low surface values of turbidity and TSS near the Avocet (third set of values) indicated very rapid initial settling, which would occur with coarser sediments than would be expected at the site, about six miles northeast of the Bonnet Carre' Spillway outlet. The surface values measured near the other two dredges were also lower than would have been expected, based on results of other shell dredging surveys.

Despite the limitations and inconsistencies of the referenced dredge plume surveys, it can be generally stated that the surface turbidity

plumes begin as highly concentrated masses of sediment and shell fragments at or near the water surface. The dense slurry undergoes turbulent mixing in the upper water column and begins to disperse and be advected in the direction of the prevailing current.

The speed and direction of the moving dredge further affect the shape and extent of the plume as it expands horizontally in the upper water column. In a matter of minutes after dredging ceases, surface turbidity normally decreases to near background levels unless salinity is well below 1.0 ppt. Under fresh or nearly fresh conditions, as occasionally occur in western Lake Pontchartrain during high runoff periods, flocculation will be retarded and visual surface turbidity will be much more persistent. The areal extent of surface turbidity beyond the dredge discharge is a function of surface currents and rates of flocculation and settling of the clay particles. Subsurface turbidity continues for longer time periods and extends farther from the discharge site. Surface and subsurface plume dimensions and intensity gradients are directly determined by currents within the water column, which may not be uniform in speed or direction.

Under quiescent conditions, the plume will expand slowly and remain more highly concentrated than under windy, turbulent conditions, when it affects a larger area but becomes less intense. Greater degrees of turbulence and faster current speeds also act to retard settling times of fine sediments, keeping them in suspension over longer distances from the dredging sites. Water depths ultimately limit the extent of subsurface plume travel.

Computer simulations of shell dredge discharge into Lake Pontchartrain were performed by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) in September 1987 using the DIFCD open-water disposal model. Sediments discharged from a propeller-driven dredge were simulated for up to 3,600 seconds (one hour) using typically occurring values of dredging rate, forward speed of the dredge and tidal

currents, and a range of sediment grain size distributions. It was determined that the descending mass of slurry material becomes entrained in the propeller wash, centered about 2.5 feet below the water surface, and is projected nearly horizontally behind the dredge in a dispersed plume of sediment particles and shell fragments. Then, as the jet velocity dissipates away from the dredge, the natural hydrodynamic forces become dominant.

Under these less turbulent conditions, flocculation and coagulation of the fine sediments can proceed, and they begin to settle out along with the coarser particles. These processes occur normally, except under very low salinity conditions when the clay and fine silt particles would remain separated and suspended in the turbidity plume for much longer periods.

Assuming normal salinity levels, all but a minor fraction of the sediments will be deposited on the bottom as a widespread fluid mud layer within an hour after being discharged from the dredge. This newly-deposited layer is estimated to average about 0.5 to 0.8 inch thick over a 50-foot wide zone along each side of the dredge path in the case of a typical sediment grain size distribution. Finer and coarser distributions would predictably be deposited as relatively thinner and thicker layers near the dredge. It was also estimated that the average thickness of deposited sediments beyond 100 feet from the dredge path would be less than 0.1 inch after one hour.

The DIFCD model was also applied to the Sheldrake, the only one of the dredges that is pushed by a tugboat, and whose discharge is not directly influenced by a propeller wash. In this situation, flocculation and coagulation begin almost immediately, and the heavier particles settle to the bottom quickly as a dense mass near the dredge path. The resultant fluid mud layer has a greater maximum thickness than that resulting from a propeller-driven dredge, and probably occupies a smaller total area of the bottom.

The DIFCD model was designed for the primary purpose of simulating dredged material behavior in the vicinity of much wider cuts and deeper depths such as occur in navigation channels and harbors. It is thus not particularly suited to the determination of maximum mound thickness that would exist within a very narrow zone near the dredge path. Its practical limit of resolution for most simulations is about 50- by 50-foot grid size. The model does not incorporate other aspects of settled material dynamics, including consolidation and shear forces that would tend to further reduce layer thicknesses and promote lateral spreading. Neither does it simulate the intermittent currents and turbulence that occur in response to wave action, which in reality would cause still further lateral sediment movement and reduction of maximum mound thickness.

The referenced DMRP program included a field investigation of fluid mud dredged material and its relationship to water column turbidity (Nichols et al., 1978). The study objectives included observation and measurement of the nature, extent, and thickness of fluid mud in relation to its source and to turbidity at several open-water pipeline disposal sites. Other objectives included measurement of water currents and fluid mud movement, and determination of the physical properties of the mud that affect its dispersal, stability, and persistence with time.

The measurement of fluid mud characteristics requires highly specialized equipment, particularly during the dredging operation. Water column turbulence is caused by the dredge discharge and propeller wash, and near the bottom by the dredge intake (fishmouth suction pipe in the case of Lake Pontchartrain shell dredges). Natural water movement and turbulence results from tidal currents and wind-induced waves, and constantly varies with time. The fluid mud immediately begins to consolidate upon settling to the bottom, and also to move away from its initial location in response to gravity and bottom currents.

The referenced field investigation used a specially designed and constructed sensing apparatus for <u>in situ</u> measurements of the fluid mud at two sites, including Mobile Bay, Alabama. This was necessary because of the physical disturbances of the mud that would occur if samples were retrieved and processed in a laboratory. The sensors measured sediment density, turbidity, and current speed with depth. A dual-frequency fathometer was used to locate and record the approximate positions of the fluid mud surface and base at a density of 1.30 g/cc. Water samples were taken for gravimetric analysis of suspended sediment and salinity measurements. Short core and grab samples were obtained for analysis of the physical properties of the mud. Field measurements were made before, during, and after dredging operations, and under various hydrometeorologic conditions.

The following sediment parameters were measured in the laboratory: organic carbon, grain size, dry density; bulk (wet) density; water content; liquid and plastic limits, suspended sediment concentration; and shear strength. The void ratio and porosity were derived from the measured parameters.

The Mobile Bay open-water disposal site was in water depths of 3.0 to 3.8 m (about 10 to 13 ft). The wave energy regime was generally low during the field investigation. The mean tide range was 1.5 ft and the maximum tidal current was 1.4 ft/sec.

The water column was characterized as relatively well mixed, with a salinity range of 0.9 ppt at the surface to 2.7 ppt at the bottom. Ambient suspended sediment concentrations were about 40 mg/L.

The 15 analyzed sediment samples included both new dredged material and older consolidated sediment, which probably consisted of previously dredged material. Most of the samples were classified as silty clay, with a mean size of 3.2 μ. There was no observed distinction in texture between the old and new sediments. The silt-clay ratio averaged 30:70, with sand occurring in only two samples at 2 percent or less.

The new dredged material and older consolidated sediments were compared with respect to their plasticity. The liquid limit was considerably higher on the average in the new material, and the plastic limit was somewhat higher. These differences, particularly for liquid limit, indicated the greater propensity for movement (flow) of the newer material.

The organic content of the samples averaged 1.96 percent, no distinction being made between the old and new sediments. Organic matter and its particular form significantly influences engineering properties of sediments. Rashid and Brown (1975) showed that addition of 4 percent humic acid to a muddy sand increased its plasticity and remolded shear strength, and almost doubled its liquid and plastic limits. The rate of consolidation of the altered samples decreased, however, as did their rate of permeability. The Mobile Bay sediments evidenced these characteristics.

The Mobile Bay sediments were classified as active clays, according to a direct linear relationship between the plasticity index and the percent of clay fraction finer than 2 u, defined by Skempton (1953). Activity refers to the increased surface activity of the clay fraction of a sediment, e.g., the increased ion change capacity and absorption of water with decreasing grain size. The Mobile Bay sediments are predominantly montmorillonite, with kaolinite occurring in a lesser abundance (about a 4:1 ratio). The high montmorillonite content was responsible for the high liquid limit values of the new dredged material. Because of the relatively greater surface area of montmorillonite, larger amounts of water are attracted to the particles, as both absorbed and free water. The average water content of the sediments (before dredging) was 165 percent dry weight, and the bulk density was less than 1.3 g/cc.

The foregoing descriptions of the Mobile Bay sediment properties are given for the purpose of projecting a comparison with observed dredged sediment behavior in Lake Pontchartrain., The referenced GSRI study of

shell dredging in Lakes Pontchartrain and Maurepas in 1974 included physical characterization of the sediments at 22 baseline stations, and three stations at or near dredge cuts. In 1978 and 1979, Sikora _et al._, (1981) collected sediment and water samples from two active dredging sites and from an undredged control site. Laboratory sediment consolidation was observed on samples obtained directly from a dredge discharge pipe in the northwestern part of the lake. In 1981, 13 sediment stations throughout the lake were sampled by Sikora and Sikora (1982) and analyzed for percent organic carbon and bulk density. In 1986, Taylor Biological Company retrieved bottom sediment samples at the midlake dredging and control sites that had been sampled by Sikora _et al._, (1981) in 1978, and at other dredged sites in the southeastern and northwestern parts of Lake Pontchartrain. Physical sediment characteristics were measured for each sample and organic carbon was measured for the midlake samples. Figure C-2 shows the GSRI sampling stations, Figure C-3 shows the Sikora sample locations, and Figure C-4 shows the distribution of bottom sediments in Lake Pontchartrain.

The bulk density of a sediment varies inversely with its water content, and also with its organic content (Figure C-5). Figure C-6 shows the curvilinear relationship between bulk density for an inorganic sediment (specific gravity = 2.65) and its water content (Barnard, 1978). The measured bulk density and water content values for bottom sediments at the 22 baseline stations in Lake Pontchartrain (GSRI, 1974) are also shown, with their best-fit curve. It is presumed that the vertical (bulk density) difference between the two curves is primarily attributable to organic content, although the presence of shell within the core samples may also be a factor. The GSRI investigation did not include measurement of sediment organics or shell fractions, so this presumption cannot be directly verified.

Figure C-6 also shows plotted values for replicate core sediment samples taken at the referenced midlake sites, and in southeastern Lake Pontchartrain in the vicinity of active dredging. The considerable

scatter of these data along both sides of the reference (inorganic sediment) curve presents a rather confusing picture. The only corresponding organic content data are for two surface samples at midlake. Although one sample measured 61 percent higher in total organic carbon than the other, the averaged bulk densities of the near-surface replicates were practically the same, so no direct inference can be drawn about the effect of organic content on the sediment densities. One of the three near-surface replicates at the former midlake dredging site (DX-A) and one of the three control site near-surface replicates (DC-B) were each identified as containing significant quantities of shell and shell fragments. Replicate DC-B plots lower with respect to the reference curve than DC-A and DC-C, while replicate DX-A plots between the other two dredging site replicates. So, at least for the control site, it could perhaps be inferred that the presence of lower-density shell material caused the DC-B sample density to be relatively lower.

The plotting positions of the lower-level midlake replicate samples, representing an average subsurface depth increment of 25 cm (or from 17 to 42 cm) display an erratic pattern with respect to each other, and to each of their corresponding near-surface replicates (0 to 17 cm average depth increment). The bulk density value of 1.01 given for subsurface replicate DC-A is apparently erroneous. It would normally be expected that the subsurface samples would be more consolidated (denser) than their near-surface counterparts, but it is also recognized that vertical stratification including shell and organic matter layers is a possible condition that could produce a nontypical density gradient in a given sediment core. Grain size analyses of the near-surface samples showed little variation, with D-50 (median grain size) values ranging from .0005 to .001 mm for the six replicates. Many more samples would be needed at the midlake site before definite conclusions could be reached about bulk density variance with respect to its primary contributing factors. Also, since the experimental dredging had been conducted some 8 years before in an area otherwise restricted to dredging, it is to be expected that natural processes causing sediment redistribution and consolidation

during that period would have tended to overcome whatever differences in sediment properties that had initially arisen because of the dredging activity. Therefore, any density differences between the dredged and control site sediments that were observed in 1986 should be regarded as largely coincidental, especially in view of the small number at samples and their apparent nonhomogeneity.

The laboratory consolidation experiments conducted by Sikora et al. (1981) on dredged sediments (1978-1980) revealed relatively slower rates of consolidation (densification through displacement of water) in the uppermost levels of the sediment column. The extent of applicability of this measured phenomenon to what really occurs in the natural setting is unknown, because tidal currents and normal turbulence in the water column, as well as gravity cause the deposited mounds of less-dense recently dredged material (fluid mud) to be redistributed laterally as well as vertically. Over time, the looser sediments near the surface of the fluid mud mounds will continue to be transported toward lower elevations, including the dredged trenches, and also horizontally subject to the speed and direction of bottom currents. These ongoing dynamic processes should cause the redeposited sediments to approach their predredged density levels much more rapidly than was observed in the laboratory.

The process of self-consolidation of the fluid mud begins where the solids concentration exceeds about 200 g/L (Barnard, 1978), which is equivalent to a bulk density of 1.13 g/cc. The bulk density of the sediment then increases, the height and slope of the mound decreases, and the rate of consolidation decreases with time, similarly to the laboratory experiment. The time required for ultimate consolidation is dependent primarily on the thickness of the deposited material and its physical characteristics, particularly its grain-size distribution.

The generally fine-grained silty clay sediments common to most of the permitted dredging areas tend to become distributed over greater

distances than coarser sediments. In the referenced Mobile Bay fluid mud investigation (Nichols et al., 1978), the deposited material had extended more than 500 m from the discharge point at a thickness of 12 cm after four days of dredging. The finer average grain size of the Mobile Bay sediment, and the greater current speeds than in Lake Pontchartrain, indicate that the lake sediments would not have migrated as far.

The average liquid limit of the Mobile Bay consolidated (undredged) sediments was 115, compared to 157 for the new dredged material, reflecting a large increase in its ease of transportability because of disrupted interparticle bonds. The Lake Pontchartrain dredged sediment physical characteristics probably experience similar changes. The average liquid limit of the baseline sediment samples in the GSRI investigation (1974) was 73, so the dredged lake sediments would be likely to spread somewhat less easily sediments. Thus, maximum fluid mud travel distances would be further shortened compared to Mobile Bay.

The lower average organic carbon content in near-surface Lake Pontchartrain sediments (Sikora and Sikora, 1982) of 1.33 percent compared to 1.96 percent in Mobile Bay favors relatively faster reconsolidation of the lake sediments, although ultimate shear strengths of the consolidated lake sediments would not be as great as if organic content were higher (Nichols et al., 1978). Shear strength of bottom sediments is indicative of their resistance to resuspension by currents or turbulence in the water column.

The Mobile Bay field measurements did not continue beyond the dredging period, so the ultimate fluid mud travel distances and reconsolidation rates are not available. A parallel field investigation of fluid mud characteristics was conducted in the James River, Virginia in 1976 by Nichols et al. (1978) which included post-dredging monitoring of the deposited material for up to 332 days. Longitudinal profiles were constructed from fathograms (depth measurements), and these data were used to calculate consolidation rates after 17, 40 and 275 days, and an aver-

age rate over the entire 332-day span. At the end of the monitoring period, the original James River mound had become reduced to about one-half of its original height and volume, with the averaged consolidation rate for the entire period being about 15 percent of the average rate for the first 17 days. Most of the James River sediment samples were clayey silt, having generally less than 5 percent sand fractions. The mean grain size of the samples was 12 u, compared to 3.2 u in Mobile Bay, 7.2 u for the Lake Pontchartrain baseline stations measured by GSRI in 1974, and 6.1 u (estimated) for the lake stations monitored by Sikora in 1981. The shallow (2.4 to 3.6 m) disposal area in the James River experienced much faster mean currents (41 cm/sec) than typically occur in Lake Pontchartrain (8 cm/sec). Mobile Bay disposal site currents averaged 28 cm/sec.

The James River dredging discharge was confined to a small area for the 10-day dredging period. The deposited material formed a mound-like layer 1.8 m thick near the discharge point, becoming less than 0.3 m thick at a distance of 450 m. Movement of the near-surface mud was highly variable. At densities less than 1.10 g/cc, current speeds in the upper mud layers varied from 4 to 19 cm/sec, compared to the mean tidal current of 41 cm/sec. At densities greater than 1.10 g/cc, speeds were further diminished.

The Mobile Bay and James River field studies demonstrated a number of important characteristics of fluid mud behavior. Soon after initial deposition, the upper mud layers had traveled several hundreds of meters from the points of discharge. The fluid mud mounds begin to spread asymmetrically in response to prevailing currents and movements of the discharge pipe. All but a small fraction of the discharged slurry accumulated as dense fluid mud suspensions with concentrations of 10 to 480 g/l. Movements of the material were highly variable in time and space, with flow rates decreasing rapidly as bulk density increased from about 1.00 to 1.10 g/cc. At the James River site both the height and volume of the fluid mud mound had decreased by about one-half less than

one year after the dredging. The discussion of impacts of Lake Pontchartrain shell dredging is based in part on these study results.

Referring again to Figure C-6, the measured data from the southeastern Lake Pontchartrain dredging site are seen to vary widely both in bulk density and water content. It should be noted that the average depth to sediment surface in the dredge cut (station 3) was about 18 inches more than outside the cut. Since most of the duplicate samples varied so widely with each other, particularly in water content, it is difficult to draw meaningful conclusions about physical relationships. Station 1, located 100 ft southeast of a buoy marking the dredge path, showed by far the least variance in both the near-surface and subsurface duplicate samples. The dredge cut subsurface samples (station 3) were consistent, but the near-surface duplicates differed considerably, by 0.09 g/cc in bulk density and by 28 percent in water content, with each of them plotting above the reference curve. Stations 2, 4, and 5 showed much greater variances in the near-surface or subsurface duplicates, or in both, than the other samples. One possible explanation for the degree of variance might be an erratic pattern of discharge within the sampled area because of the dredge's path.

The plotted near-surface sediment sample data from the southeastern lake dredging site represent averages of approximately equal increments of about 8 or 9 cm each. If the subdivided data (not shown) are examined along with the underlying subsurface data representing an average 26-cm increment, it can be seen that, for 6 of the 10 samples, the top increment had the lowest bulk density, and the middle increment had the highest density within the sample core. Nine of the ten samples showed the lowest bulk density in the top increment of the sample. It is presumed that the new dredged material would have been entirely within the top few centimeters of each sample, considering the constant forward movement of the dredge which should have prevented thick accumulations from occurring.

Shell dredging has been prohibited in Lake Maurepas since 1984 when it was concluded by the DEQ that sustained higher than normal levels (above State standards) of turbidity and suspended sediment were directly attributable to the dredging activity. Aerial surveillance of the lake during May and June 1983 had revealed persistent, lakewide extreme turbidity levels. Lake Maurepas continued to be monitored in subsequent months to determine recovery time to normal conditions and to develop a data base of seasonal variations of turbidity and other water quality parameters.

After restricting activity to one dredge throughout December 1983, rather than the three dredges previously allowed to operate, it was determined that lakewide turbidity levels remained extremely high and far greater than would be expected from natural hydrometeorologic conditions. Mean turbidity levels of 200-300 NTU's, and maximum levels of 600-950 NTU's were recorded during dredging. The normal, without-dredging turbidity in the lake is believed to be less than 50 NTU's.

In August 1984, the Water Pollution Control Division of DEQ reported that, even when one dredge was operating for a brief time period, unacceptable water quality degradation occurred, unlike in Lake Pontchartrain which was capable of reasonably rapid recovery. It was therefore recommended that shell dredging be prohibited in Lake Maurepas until the industry could demonstrate that generation of sustained high turbidity and suspended sediment levels could be precluded.

The reasons given by DEQ for the distinct differences between water quality effects in the two lakes were: the relatively smaller size and depth of Lake Maurepas; fresh or very low salinity levels in Lake Maurepas; and likely differences in sediment characteristics and deposition patterns in the lakes. Although the data and analyses were not so thorough as to be completely conclusive regarding the specific causes for higher Lake Maurepas turbidity, it appears that shell dredging operations are primarily responsible.

It has been estimated that the seven shell dredges designated to operate in Lake Pontchartrain are active about 60 percent of the time, on the average. If dredging intensity were evenly distributed throughout the 44 percent of the lake where it is permitted, it would take about 4.0 years for the entire area to be dredged. According to Bahr et al. (1980), the northwestern part of the lake and the mideastern part between the Causeway and South Point have been most intensively dredged, and the western and southwestern portions have been dredged least intensively. Figure C-2 shows the areas of Lakes Pontchartrain and Maurepas that are restricted from shell dredging.

The weighted distribution of sediment types within these most intensively dredged areas was estimated by Bahr et al. (1980) as: silty clay, 45 percent; clayey silt, 25 percent; sandy silt, 10 percent; silty sand, 10 percent; clayey sand, 5 percent; and clay, 5 percent. Typical salinity ranges in the referenced northwestern and mideastern lake areas are: 1.0 to 2.5 ppt; and 3.0 to 5.5 ppt, respectively. These are potentially significant influencing factors on turbidity plume generation, settling characteristics, and fluid mud behavior.

The most noticeable impact of shell dredging is the highly visible surface turbidity plume that is generated. Near-surface turbidity plumes are caused by clay and fine silt in the immediate vicinity of the discharge. Except under fresh or nearly-fresh water conditions, flocculation occurs and the composition of suspended near-surface sediments soon becomes limited to clay particles as the silt and flocculated clay begin to settle out.

If the end of the discharge pipe is submerged below the water surface and/or directed downward rather than outward, the near-surface turbidity levels will be relatively lower. Two of the Lake Pontchartrain shell dredges have been modified in this respect (Steimle and Associates, 1985). As described earlier, the shape, size, and rate and direction of horizontal movement of the turbidity plume beyond the discharge location

rapidly become a function of the currents and of turbulence within the water column. For a brief time after discharge, the propeller wash and speed and direction of the dredge are the dominant influencing factors. The initial momentum imparted to the plume by the moving dredge gradually diminishes with time at a rate governed by the hydrodynamic regime. Water column turbulence prolongs the suspension times of discrete sediment particles, but also increases the frequency of interparticle collisions, thus promoting floc formation and accelerated settling rates. Higher current speeds produce a longer, more narrow turbidity plume than slow currents, which produce a more rounded plume that eventually occupies a larger area of the lake. The migrating plume proceeds outward in the general direction of the currents, and slowly downward through the water column until it impacts the lake bottom, at water depths normally between 10 and 16 feet.

The dredged sediments containing higher percentages of clay and fine silts produce the most dense and persistent turbidity plumes, with generally no more than 3 and perhaps less than 1 percent of the discharged slurry solids actually contributing to the plume when ambient conditions permit normal rates of flocculation and coagulation of clay particles.

According to the DMRP studies, clay minerology and organic content affect rates of flocculation and settling times, with the organic content having the greater relative influence (Wechsler and Cogley, 1977). In general, it was found that higher organic levels in the sediments tended to produce more rapid turbidity reduction (increased settling rates). In dredged areas of Lake Pontchartrain, measured sediment organic levels are quite variable, with the northwestern sediments having somewhat higher average organic content than the mideastern sediments.

Only during high runoff periods during the late winter and spring months are northwestern lake salinity levels likely to fall much below 1.0 ppt. During these periods, flocculation rates will likely be reduced

and turbidity will be more persistent in the water column. Mideastern lake salinity would not be expected to fall below 1.0 ppt except during Bonnet Carre' Spillway operations. Since lake waters are more naturally turbid during low salinity periods, however, the relative influences of dredge-induced turbidity during these periods are correspondingly less.

Occasionally high wind speeds over the lake during frontal passages and at other times are capable of resuspending bottom sediments, and also of prolonging the effects of turbidity from dredging. Tidal currents in the permitted areas are usually too slow to resuspend the dormant sediments, but influence the length of travel and duration of suspended sediments in the water column.

Sheng and Lick (1979) related the incipient motion (resuspension) of bottom sediments to the bottom shear stress coefficient, which is a function of the physical nature of the sediments. Bottom stress due to wind-generated waves is related to the wave characteristics (height, period, length) and the water depth. Although Lake Pontchartrain sediments have not been specifically analyzed to determine their critical stresses for movement or resuspension, Swenson (1980) estimated, on the basis of experiments on sediments in other water bodies, that the silty clay sediments comprising nearly half of the most intensively-dredged areas would become totally resuspended at a shear stress of about 10 dynes/cm2. The wave height corresponding to this stress occurs, on the average, when a wind speed of 38 miles per hour is attained, a condition exceeded less than 1 percent of the time.

Although the relative coarseness (or grain-size distribution) of Lake Pontchartrain bottom sediments are not believed to be significantly changed as the result of dredging, laboratory comparisons of pre- and post-dredged sediments at other dredging sites indicates that clay mineral bonding strengths and amounts of exposed surface area may be altered by dredging (Nichols et al., 1978). Depending on the relative abundances of montmorillonite, illite, chlorite, and kaolinite, clay

surface activity levels may decrease or increase. In Mobile Bay, the high montmorillonite content of the clay was considered responsible for its heightened liquid limit values after dredging. In contrast to the clay fraction of the James River sediments, which contained relatively more illite and chlorite, the Mobile Bay dredged sediments had developed higher activity levels (become less stable) while the James River dredged sediments appeared to have become more stable than the older, undredged sediments. The central Lake Pontchartrain sediments were studied by Brooks and Ferrell (1970) and were found to have relative clay mineral abundance of about 60 percent montmorillonite, about 30 percent kaolinite, and about 10 percent illite. These proportions of minerals lie between those reported for the Mobile Bay and James River sediments, so the implication for increased or decreased activity of dredged versus older sediments in Lake Pontchartrain remains unclear.

Sikora and Sikora (1982) indicated an apparently drastic lakewide decrease in organic carbon content of the sediments compared to that measured by Steinmayer (1939). Differing methods of measurement and the lack of available supporting data for Steinmayer's work make it ill-advised, however, to attempt to draw definite conclusions about organic carbon content changes over the years. It has been demonstrated that organic content of sediments significantly affects its engineering properties (Nichols et al., 1973), including its consolidation rates, remolded shear strength and plasticity, and permeability. The limited available data on Lake Pontchartrain sediment organic content has not and cannot be coanalyzed with respect to the physical properties of either old or newly-dredged sediments, because those investigations which have included comprehensive organic carbon analyses have not also included physical characterizations of the same sediments, except for grain size distributions.

The impacts of clam shell dredging on turbidity levels in Lake Pontchartrain must be properly considered relative to other important influences, particularly tributary and Bonnet Carre' Spillway inflows,

wind wave turbulence, and shrimp trawling. Regarding short term effects, it can be acknowledged that shell dredging causes greatly elevated suspended solids concentrations and turbidity levels near the dredge, which typically become reduced to respective ranges of 1,000 to 2,000 mg/L and 500 to 1,000 NTU's within a distance of about 500 feet from the dredge. Actually, short-term turbidity levels that are generated are primarily dependent on dredge discharge capacity, solids concentrations in the discharged slurry, particle size distribution, discharge pipe and propeller configuration, dredge movement, water column turbulence and currents, and organic content of the sediment. Except under infrequent low salinity conditions, flocculation of the finer clays will occur, causing gravity settling. The turbidity plume's size and shape beyond the immediate vicinity of the dredge are controlled by hydrodynamic conditions in the lake. Maximum turbidity levels within the plume tend to diminish exponentially with horizontal distance from the discharge site, and also occur gradually lower in the water column as gravity settling of the flocculated clays continues. Maximum areal limits of the plume are dependent on prevailing currents and water depths.

Turbidity generated by tributary and Bonnet Carre' freshwater inflows to the lake is the result of transported sediments whose concentration levels are highly dependent on flow velocities. As rainfall runoff becomes translated to streamflow, the energy of the moving water causes erosion of the streambanks and scouring of the streambed to occur, and suspended sediment concentrations in the channel are greatly increased. As the freshwater discharge enters Lake Pontchartrain, its velocity is immediately reduced. The momentum of the discharge causes much of the flow and its suspended sediment load to continue moving in the same direction, but the prevailing lake currents and turbulence gradually exert more influence on the speed and direction of movement, and lateral flow will become significant.

The reduced velocities cause sedimentation of the sand and coarser silt particles, but flocculation of the clay particles will not become

significant until sufficient mixing and dilution of the fresh water with brackish lake water has occurred to overcome the repulsive forces between the negatively-charged particles. Once the hydrodyamic conditions in the lake have become the dominant forcing factors, the size, shape, and turbidity levels within the expanding turbidity plume from a tributary or Bonnet Carre' Spillway discharge will behave in the same manner as would a shell dredge turbidity plume.

As stated previously, moderate to high wind speeds over the lake cause waves and water turbulence, which prolong the suspension times of already suspended sediments, and occasionally overcome frictional forces to resuspend bottom sediments. In the absence of other turbidity-generating factors (dredging, freshwater inflow, trawling), lake turbidity due to wind-wave conditions will be governed in intensity, duration, and areal extent by the speed and persistence of the winds.

Shrimp trawling occurs in the lake on a seasonal basis, and is regulated by the LDWF. It is generally more intensive in the eastern, higher-salinity reaches of the lake. Schubel et al. (1979) studied sediment disturbance and turbidity generation by shrimping activity in Corpus Christi Bay, Texas. They concluded that maximum suspended sediment concentrations in the trails of shrimp boats were comparable to those observed in the turbid plume of an open-water pipeline disposal of dredged material in the area.

The total shrimping effort in Corpus Christi Bay in 1975 amounted to about 5,800 boat days. The trawls, varying in width from 6 to 20 m, are towed behind the boats at a speed of about one m/sec. The weighted footrope of the main net drags along the bottom and disturbs approximately the upper 5 cm of the sediment. Main trawls are fished an average of 4 to 10 hr/day. Using these data, furnished by the National Marine Fisheries Service, it was estimated that perhaps 50 to 100 million m3 of in-place sediment are disturbed by shrimping activity in a typical year. This compares to the average annual maintenance dredging volume in

Corpus Christi Bay of about 1.6 million m3 of sediment. Since about 20 percent of the surficial sediment disturbed by shrimpers is estimated to have been solid material, as opposed to less dense fluid mud, the estimated volume of resuspended dry sediment would be about 10 to 20 million m3 per year.

If it is further assumed that the in-place sediments are 15 percent solid material by volume, and that the resuspended material is distributed uniformly throughout the water column, having a typical depth of 4 m, the calculated suspended sediment concentration behind the trawl will be more than 5,000 mg/L. Actual observations of turbidity levels and suspended sediment concentrations were made at depths of 0.6 and 2.1 km, and at distances of 100 m or more astern of the estimated trawl position. The observed suspended sediment concentrations were typically between 100 and 500 mg/L. The discrepancy between the calculated and measured values was mainly accounted for, however, by the reality of nonuniform distribution of sediments in the water column, i.e., concentrations increase exponentially near the bottom.

The observed suspended sediment concentrations behind a typical shrimp trawl were similar to those observed in the turbidity plumes of the dredge Captain Clark during the same time period. The dredge's pipeline discharge rate was about 2.2 m3/sec, and the slurry was about 6.5 percent solids by volume. These values are closely comparable to those of the Lake Pontchartrain shell dredges, whose discharge capacities are between 1.3 and 2.5 m3/sec. The referenced Mobile Bay and James River dredges (Nichols *et al.*, 1978) had average discharge rates of 3.2 and 2.4 m3/sec, by comparison.

Given the estimated amount of shell dredging activity in Lake Pontchartrain of about 1500 dredge-days/year, and an average depth of penetration of the bottom sediments of about 65 cm over a trench width of 2 m, comparison with the referenced Corpus Christi Bay shrimp trawling data gives a ratio of about 1.2 times the amount of bottom sediment

disturbed annually by shell dredging in Lake Pontchartrain as by shrimp trawling in Corpus Christi Bay. Because, however, a much greater percentage of the sediment disturbed by shell dredging (perhaps 90 percent compared to the estimated 20 percent disturbed by shrimp trawling) would be considered as solid material, the ratio of mass of solid material available annually for resuspension by shell dredging becomes about 5.4 times that of the shrimp trawling. Aside from these comparisons, it should be acknowledged that shell dredge discharges occur at or near the water surface, whereas the shrimp trawling disturbance is concentrated near the bottom. Thus, both the upper water column turbidity levels and the ultimate length of a turbidity plume from a shell dredge would be significantly greater than from a shrimp boat that resuspended solid bottom sediment at the same rate as the shell dredge.

Long-term turbidity impacts from shell dredging and the other identified major influences are generally much more difficult to assess. Because of the much greater depth of penetration by the shell dredges, much more of the consolidated bottom sediments are disturbed, and their physical properties are more extensively altered than by trawling, which disturbs unconsolidated sediments for the most part. The post-dredged sediments are initially less dense than before dredging and are therefore more easily resuspendable from that standpoint than the pre-dredged sediments.

The fact that the entire lake bottom is intermittently disturbed by wind wave turbulence is undoubtedly a very important factor influencing the rate of sediment recovery to pre-dredged conditions. The temporal and spatial complexity of lake hydrodynamics, transport processes, and sediment-water interface phenomena are such that state of the art laboratory tests or analytical models would be infeasible, if not incapable, of adequately evaulating the surface sediment recovery processes, especially over long time periods.

It was stated earlier that the average tributary and Bonnet Carre' Spillway inflows to Lake Pontchartrain have been significantly higher

since the early 1970's than during the previous 15 to 20 years. It is believed that the resultant increased supply of alluvial sediments to the lake during the more recent period has to some degree been responsible for increased average lakewide turbidity levels since the 1950's and 1960's. It is also believed that the ongoing activities of shell dredging and shrimp trawling have each been partially responsible for the overall long-term turbidity increases, with shell dredging having somewhat more of a total impact than trawling. The intensity of shell dredging increased greatly during the 1960's and 1970's, but has gradually declined in intensity since the mid-1970's. If this trend continues, lake turbidity levels could become more stable or perhaps even begin to decline, other factors being equal.

The phenomenon of fluid mud generation by open-water dredging and disposal activities has been addressed in some detail in the preceding pages. Inferences have been drawn about the likely extent and rates of movement of fluid mud along the bottom in Lake Pontchartrain relative to other water bodies where field research has been conducted. Further insights were gained from computer simulations of the fluid mud deposition patterns of Lake Pontchartrain shell dredge discharges. Although it is acknowledged that most of the discharged sediment does not immediately return to the dredged trench, it is nevertheless stated that, within reasonable periods of time, wave turbulence and tidal currents tend to smooth the bottom contours by moving the less dense, unconsolidated upper layers of deposited material to lower elevations in adjacent areas.

Little can be said about the life expectancy/rates of filling of dredged trenches because hardly any direct quantified information is available. It is surmised, however, that the trenches tend to become virtually filled within moderate time periods. This opinion is based on the following factors known to be effective: (1) Some of the discharged material falls directly back into the trenches; (2) Further infilling occurs within minutes to days after dredging as the unconsolidated upper

layers of the dredged sediments are transported by bottom currents and/or gravity into the trenches; and (3) Intermittent disturbances of the bottom by wind-generated waves and turbulence naturally redistribute the sediments, and effect a significant net transport of surface sediments from higher elevations (mounds) to lower elevations (trenches) over longer time periods.

The continuous forward motion of the dredges assures that the deposited material does not become initially concentrated as thick mounds in small areas. Therefore, the burial and destruction of sedentary benthic organisms by the sediments would be less extensive than if the discharge sites remained stationary for long periods. Dredged clay sediments are known to experience certain physical changes that affect their behavior, including altered plasticity and surface activity (water adsorption and ion exchange capacity characteristics) (Nichols et al., 1973). Those clay sediments having appreciable organic carbon contents are affected in their behavior during and after dredging as the result of complex interactions between the clay minerals and organic material. The precise nature of these interactions and their resultant effects on particular sediments cannot be determined without rigorous testing and analyses.

In summary, primary impacts to the lakes resulting from physical disturbance of the bottom sediments by shell dredging include short-term increases in levels of total suspended sediments and turbidity, a potential contribution to the apparent long-term increase in lakewide turbidity, and the creation of a layer of fluid mud.

Regarding short-term turbidity effects, it is well documented that shell dredging causes greatly elevated suspended solids concentrations and turbidity levels near the dredge. GSRI (1974) conducted a study and reported that turbidity returned to ambient conditions near the water surface at a distance of approximately 1,000 feet. It is acknowledged, however, that the shape and areal extent of the turbidity plume varies

depending on the speed and direction of the moving dredge and hydrometeorological conditions. Surface turbidity normally decreases to near background levels very rapidly after passage of the dredge, particularly if salinities are above 1.0 ppt. Under fresh or nearly fresh conditions, turbidity is more persistent. Since only about one percent of the total area of Lake Pontchartrain is affected by this short-term turbidity at any given time, it is not considered significant.

The extent to which shell dredging has contributed to the apparent long-term increase in lakewide turbidity levels is unknown. It is reasonable to assume that the less consolidated sediments that occur for a period of time following dredging activities are more susceptible to resuspension by wind and wave activity, thereby contributing to increased turbidity levels. However, a variety of other factors have also contributed to the long-term increase in turbidity. The fact that turbidity levels prior to the advent of shell dredging are unknown, combined with the influences of a variety of other factors that affect turbidity, make it impossible to quantify the impacts of shell dredging on long-term turbidity increases.

Shell dredging generates thin layers of fluid mud along the dredge path that are estimated to average about 0.5 to 0.8 inch in thickness within a 50-foot width along each side of the dredge path, and that become less than 0.1 inch thick at distances of 100 feet or more from the dredge. The upper, less-dense portions of the fluid mud remain subject to vertical and lateral movement caused by gravity, consolidation, and bottom currents. The recently-deposited sediments may also be disturbed by additional crossings of previously-dredged paths.

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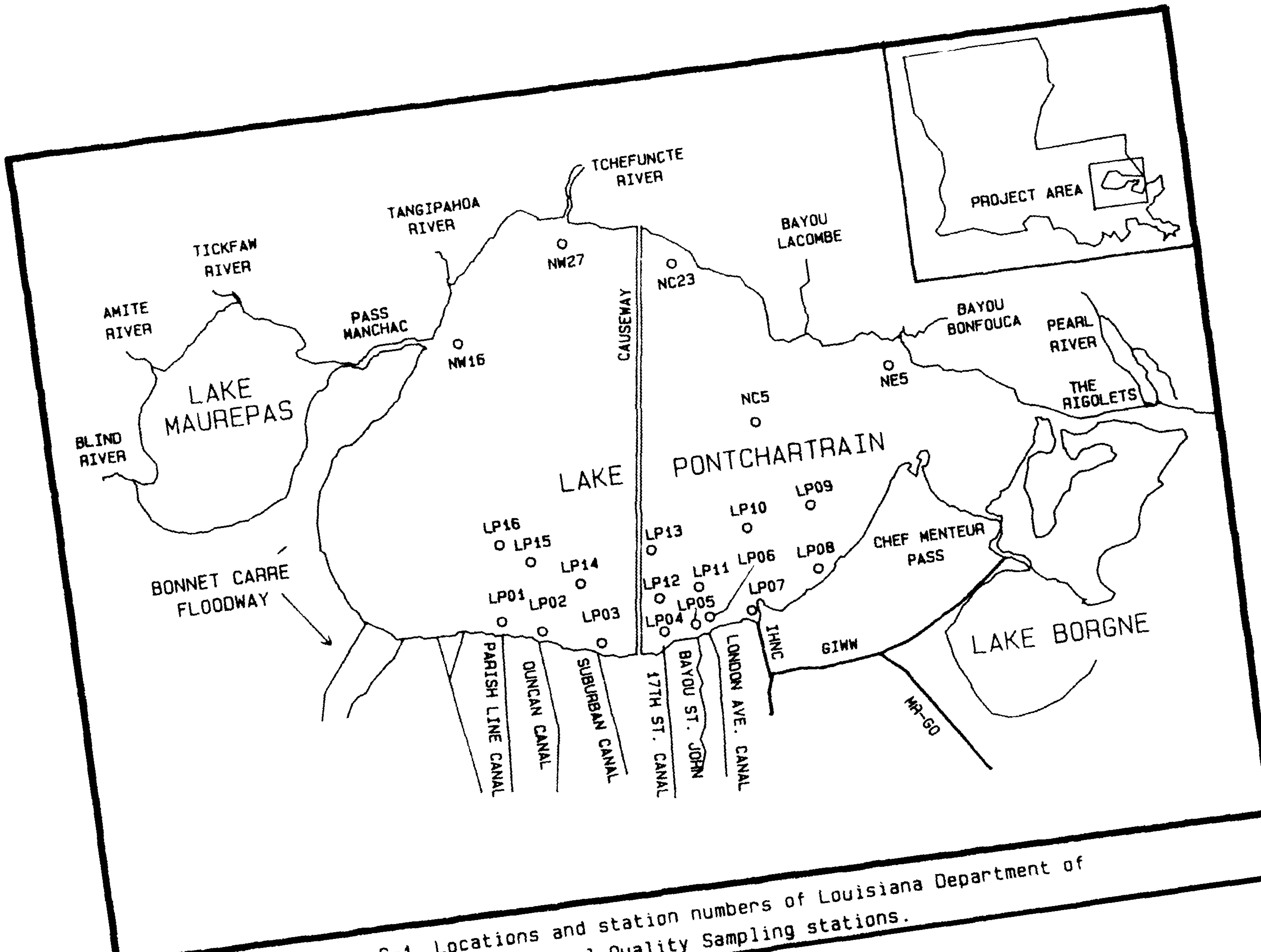

Figure C-1. Locations and station numbers of Louisiana Department of Environmental Quality Sampling stations.

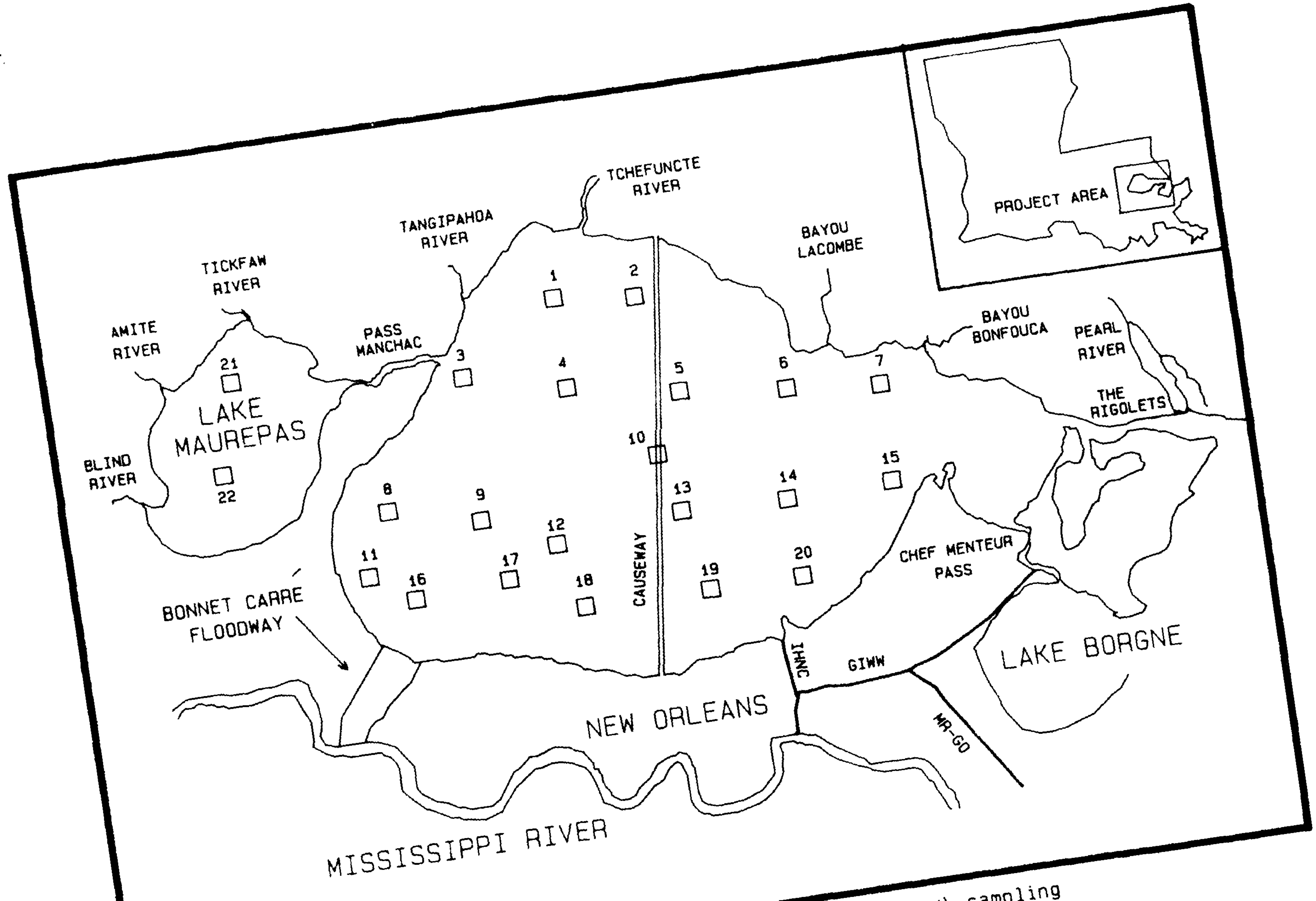

Figure C-2. Approximate locations of GSRI (1974) sampling stations in Lakes Pontchartrain and Maurepas.

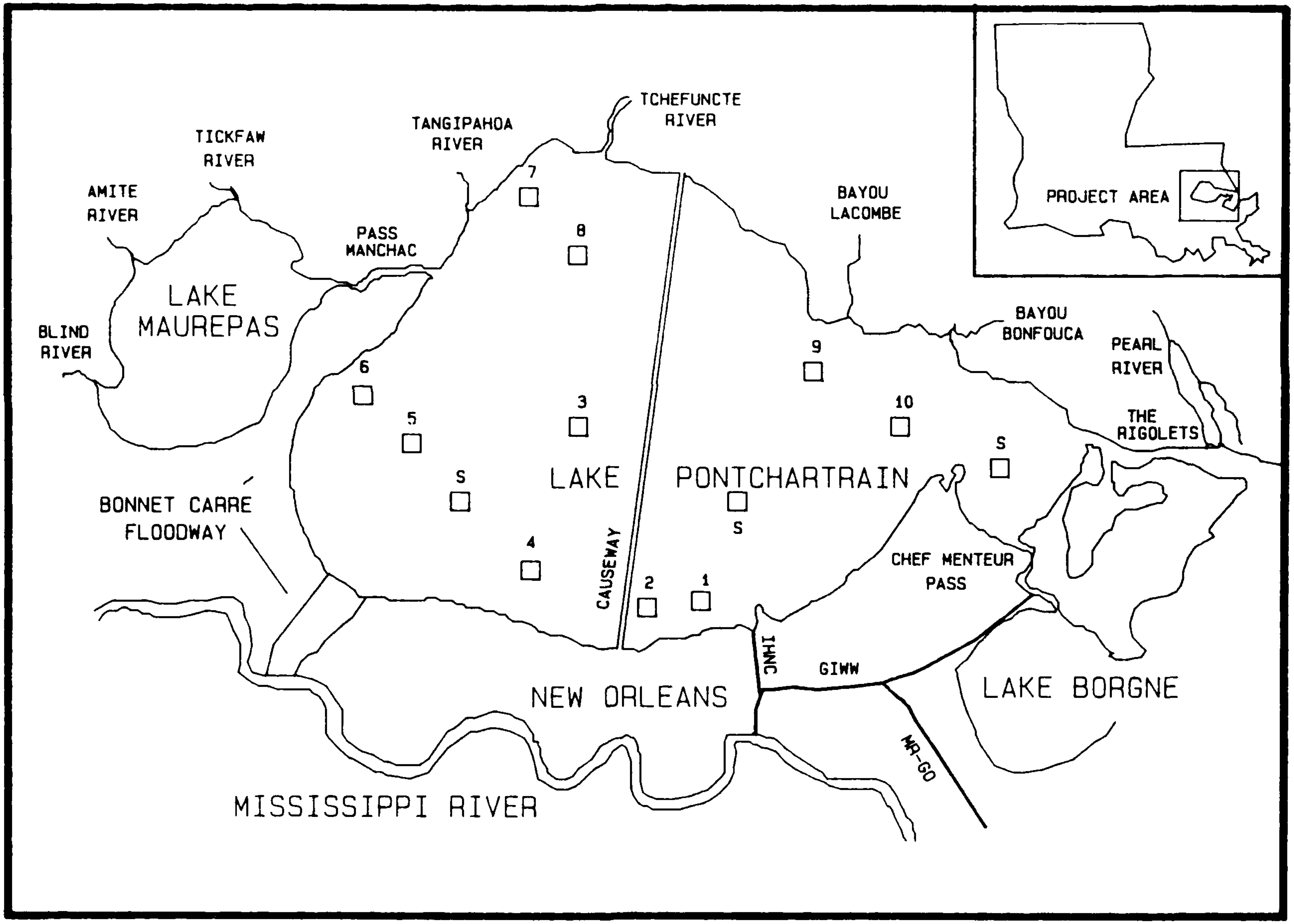

Figure C-3. The ten monthly stations and three seasonal stations sampled by Sikora and Sikora (1982).

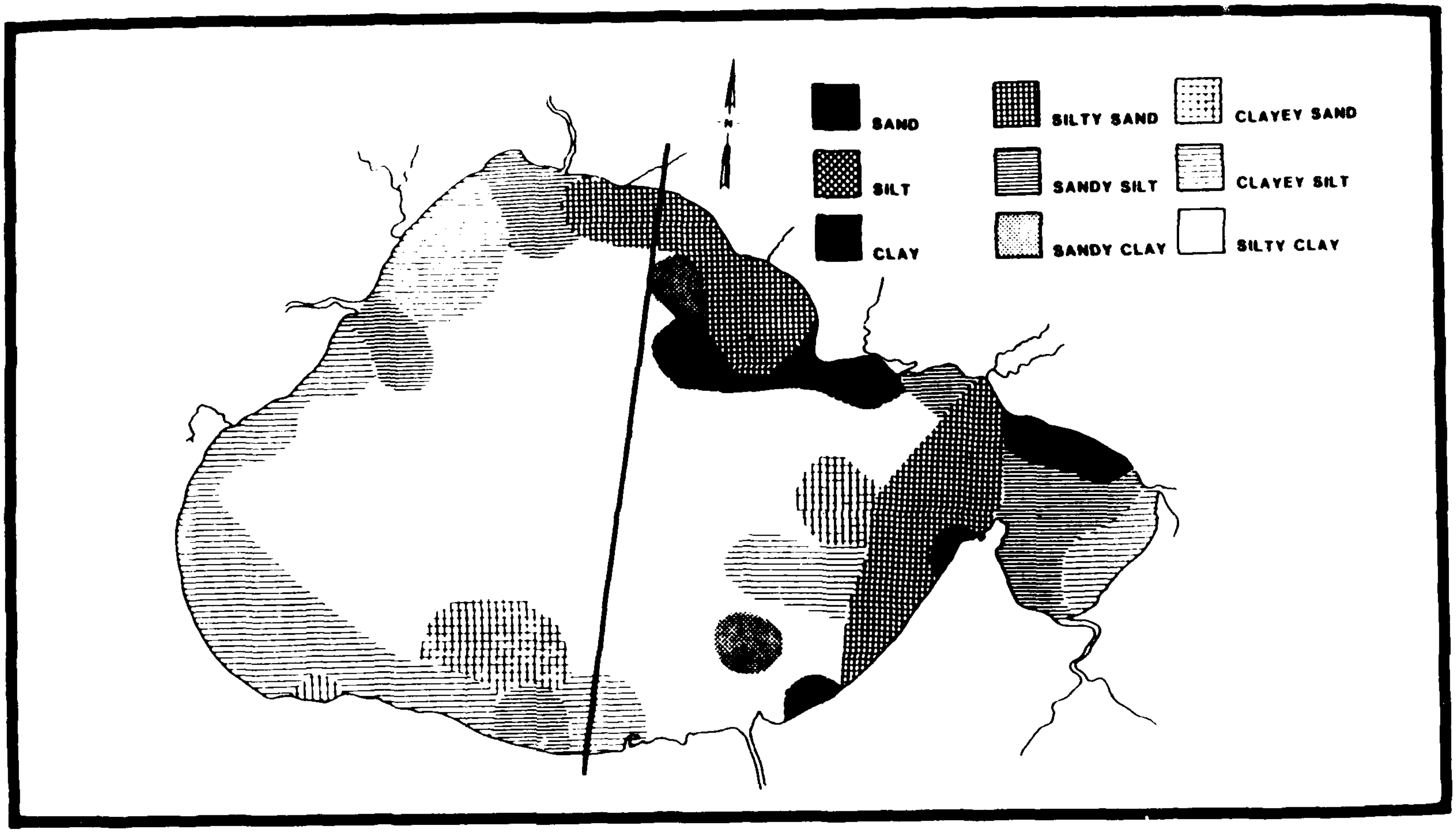

Figure C-4. Distribution of sediment types in Lake Pontchartrain (Bahr et al., 1980).

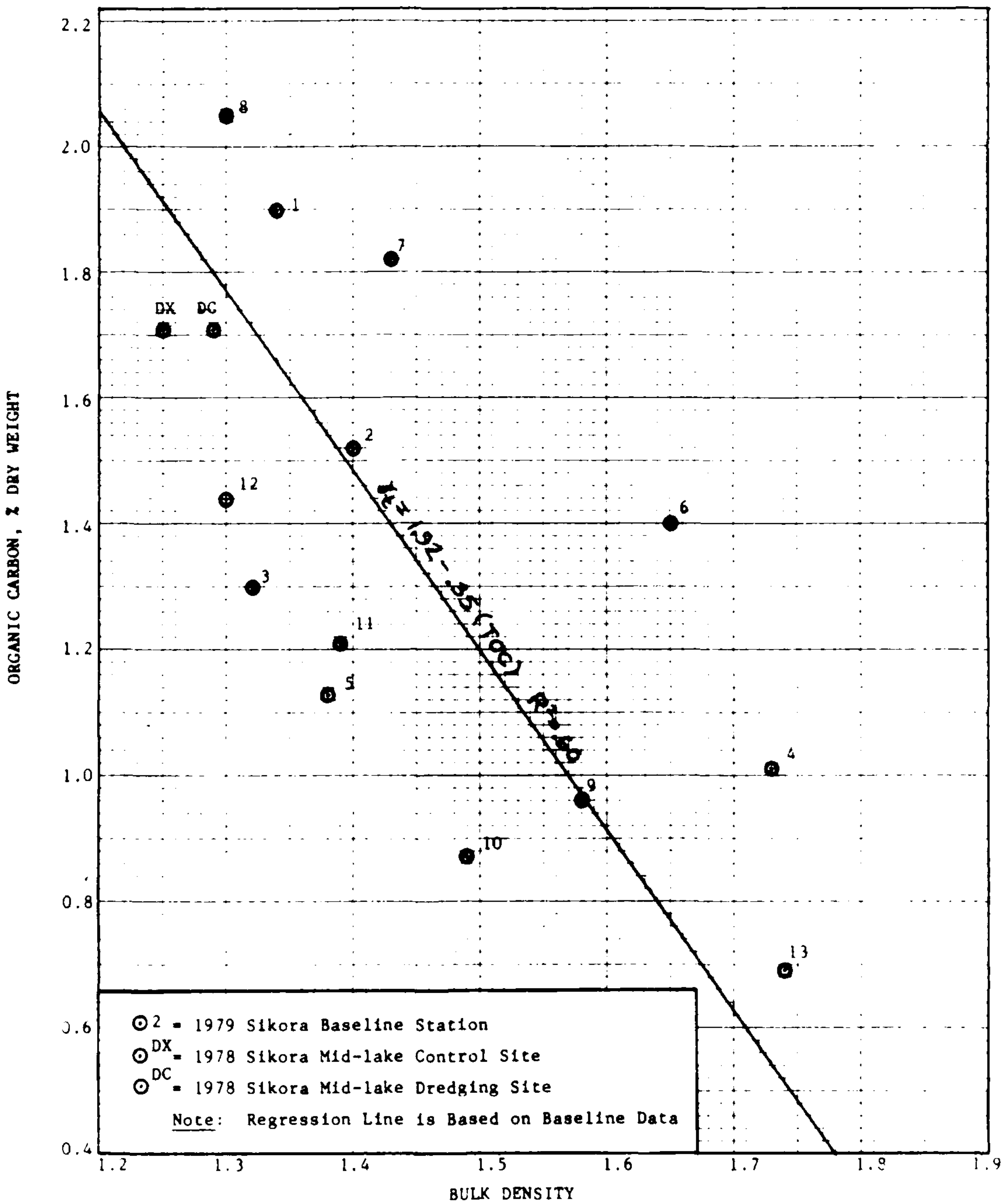

Figure C-5. Bulk Density and Organic Content of Lake Pontchartrain Bottom Sediments.

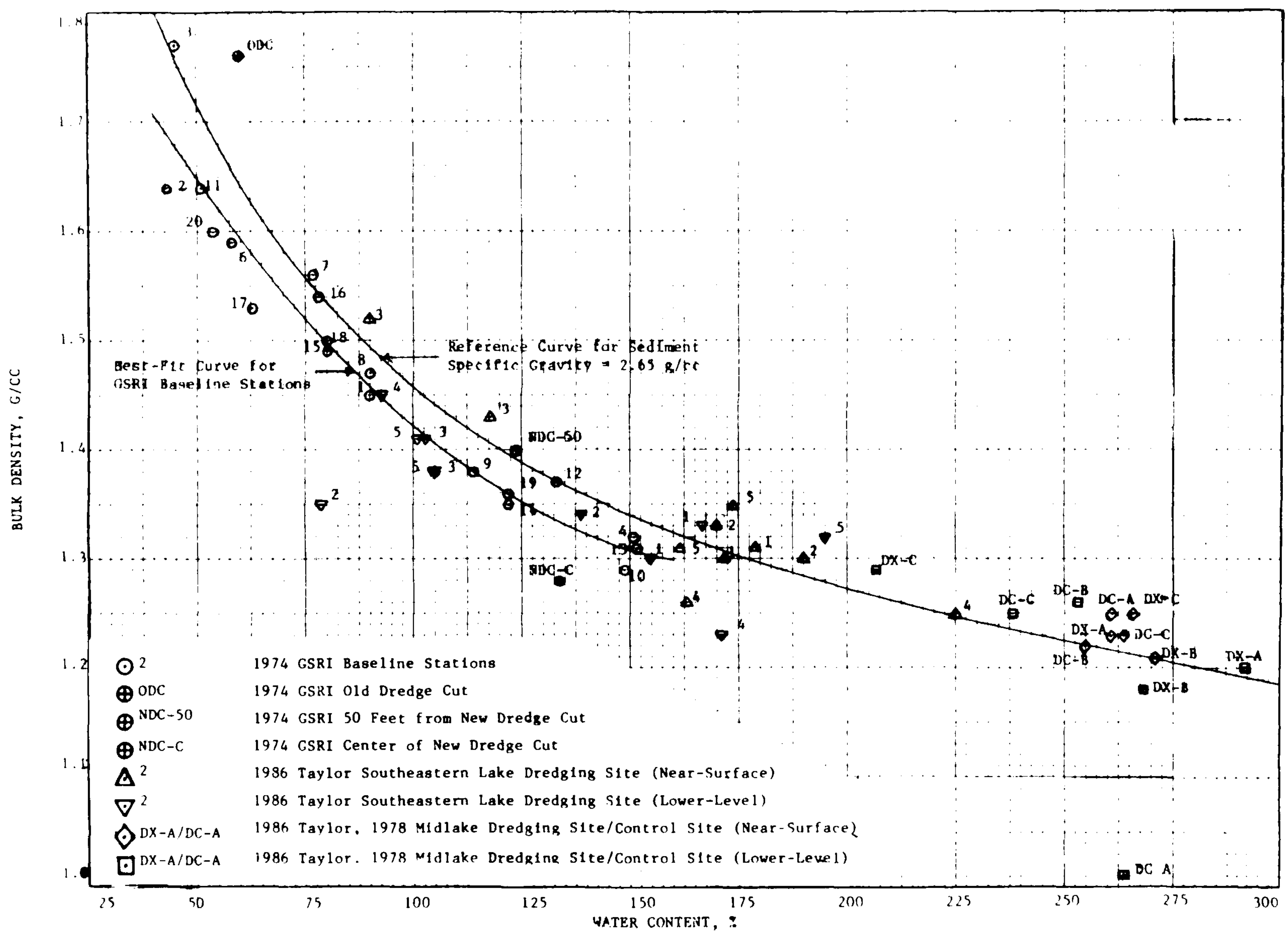

Figure C-6. Bulk Density and Water Content of Lake Pontchartrain Bottom Sediments

APPENDIX D

BIOLOGICAL ENVIRONMENT

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BIOLOGICAL ENVIRONMENT

Introduction

This appendix contains additional technical information concerning existing conditions and impacts for biological resources including grassbeds, benthos, and fisheries.

Grassbeds

Submerged grassbeds commonly occur in inland and coastal waterbodies and are important aquatic habitats. Species composition varies from one location to another due to differences in environmental conditions. The value of estuarine grassbeds has been well documented (Stevenson and Confer, 1978; Orth and Moore, 1984; Thompson and Fitzhugh, 1985). They provide a source of food for waterfowl, fish, and other aquatic organisms, nursery habitat for a variety of estuarine-dependent finfish and shellfish, assimilate excess plant nutrients, remove certain pollutants from the water column, and produce oxygen. They also serve to stabilize sediments, reduce shoreline erosion, and cause precipitation of suspended particles, thereby increasing water clarity. The primary grassbeds in the Lake Pontchartrain area presently occur along the north-eastern shore, in Lake St. Catherine, and off South Point and Point aux Herbes (Figure D-1). However, in past years, grassbeds occupied large areas along the southern shore of the lake. No grassbeds have been reported in Lake Maurepas. All common and scientific nomenclature of plants mentioned below follow Montz (1975a, 1975b).

Suttkus et al. (1954) provided the first report of submerged aquatic vegetation in Lake Pontchartrain. They found four species of submerged aquatics in their study, including Eleocharis sp. (spikerush), Ludwigia sp. (waterprimrose), Ruppia maritima (widgeongrass), and Vallisneria americana (wildcelery). Submerged vegetation occurred at depths up to six feet.

Perret et al. (1971) estimated that the grass beds on the northern shore of the lake covered about 20,000 acres, but this was not based on detailed investigation. Montz (1978) published a report which accurately described the distribution, composition, and relative abundance of the submerged vegetation in Lake Pontchartrain. The report was based on sampling conducted in 1973 at a total of 102 stations. In addition to the previously reported species, he noted Najas guadalupensis (southern naiad) throughout the north shore area. He also reported Potamogeton

perfoliatus (pondweed) to be abundant off Point aux Herbes. Montz calculated that about 2,000 acres of waterbottoms on the northern shore were vegetated with submerged aquatics.

Turner *et al*. (1980) compared data from Suttkus and Montz and estimated that the areal extent of widgeongrass and wildcelery beds declined by about 30 percent between 1954 and 1973. Southern naiad and pondweed appeared to expand in range during this period.

Thompson and Verret (1980) recorded occurrence of submerged aquatic vegetation while conducting a study of nekton in the lake. In addition to previously noted species, they encountered *Cabomba caroliniana* (fanwort), *Myriophyllum spicatum* (Eurasian watermilfoil), and *Ceratophyllum demersum* (coontail). Thompson and Fitzhugh (1985) concluded that significant changes had occurred in the distribution and composition of the grassbeds over the last 25 to 35 years. Wildcelery and widgeongrass experienced a reduction in acreage and southern naiad and Eurasian watermilfoil seemed to expand their ranges.

Mayer (1986) conducted a detailed study of the grassbeds in Lake Pontchartrain. A total of 107 stations were sampled. Station selection was coordinated as much as possible with Montz to allow comparison of the results of this study with the information from 1973. Seven species of rooted macrophytes were found in the study including wildcelery, Eurasian watermilfoil, widgeongrass, southern naiad, *Potamageton pusillus* (slender pondweed), pondweed, and *Zannicnellia palustris* (horned pondweed).

The largest acreage of grassbeds in the lake was on the northern shore and consisted of wildcelery, widgeongrass, Eurasian watermilfoil, and southern naiad. These grassbeds extended offshore an average of about 100 meters, with a maximum offshore extension of about 350 to 400 meters. East of the Southern railroad trestle, grassbeds were generally localized, sparsely populated, and extended less than 5 meters from shore.

Total areal coverage of submerged aquatic vegetation in Lake Pontchartrain was about 981 acres. Approximately 80 percent occurred on the northeastern shore between Green Point and Big Point (Figure D-1). Eleven percent occurred in the Point aux Herbes/South Point area. The remainder of the grassbeds were distributed on the eastern portion of the lake, with very little growth along the southern shore and virtually no vegetation in Lake Pontchartrain west of the Causeway.

The areal extent of grassbeds decreased approximately 50 percent between 1973 and 1985 (Mayer, 1986). Significant changes in the distribution of submerged aquatics has occurred in several areas of the lake. On the southern shore, from Indian Beach to South Point, there has been a high loss of grassbeds. In comparison with earlier studies, it is obvious that the large beds of wildcelery and widgeongrass that were once present are nearly completely gone. Additionally, except in the area of Bayou St. John, vegetation in the lake between Indian Beach and the IHNC disappeared between 1954 and 1973 (Turner et al., 1980). Decreases in the areal extent of grassbeds have also occurred on the northern shore between Pass Manchac and the Causeway. Previous investigators reported submerged plant growth in this area. However, during Mayer's surveys, no submerged aquatic vegetation was encountered over this entire area.

It also appears that the dominant grassbeds in the lake are not found at the same depths as they were historically. Suttkus et al. (1954) reported wildcelery and widgeongrass up to six-foot depths. Montz (1978) found extensive wildcelery beds growing at six feet off Green Point, Goose Point, and Point Platte. Mayer (1986) reported the maximum depth regularly noted for grassbed occurrence was about four feet.

The species composition of grassbeds has also changed dramatically in the lake. There has been widespread colonization of Eurasian watermilfoil, an introduced species. It was not encountered in Montz's 1973 surveys, whereas it is presently a dominant submerged aquatic in the lake and is found at greater depths than most other species. While the dominant native species have experienced significant reductions in

abundance, Eurasian watermilfoil has expanded its range in many parts of the lake.

The potential causes of the documented decline in acreage and changes in species composition of the grassbeds in Lake Pontchartrain are varied, complex, and more than likely synergistic in effect. Mayer (1986) discussed these possible causes in some detail. Factors which may adversely affect grassbeds include the following:

- Increased turbidity
- Elevated nutrient levels
- Runoff from urban and agricultural areas
- Input of fine-grained sediments
- Periodic openings of the Bonnet Carre' Spillway
- Saltwater intrusion
- Tropical storms and hurricanes
- Pathogenic microbes and diseases
- Herbivory by livestock, turtles, and waterfowl
- Fishing for softshell crabs in the grassbeds
- Shrimping
- Competition from introduced species such as Eurasian watermilfoil
- Natural fluctuations in abundance

Most of these issues are discussed further in other portions of this report.

There has been considerable interest regarding turbidity in the lake and whether it has increased over the years as a result of man's activities, including shell dredging. Stone (1980) estimated there has been a 50 percent increase in turbidity in the lake since the 1950's. This is based on comparisons of mean Secchi disc readings from Darnell, 1953, reported in Darnell (1979), Stern and Stern (1969), Tarver and Savoie (1976), and Stone (1980). Average water transparency ranged from

about 140 centimeters (cm) as reported by Darnell to 63 cm reported by Stone.

There is considerable seasonal variation in turbidity in the lake as well as a strong relationship between turbidity and salinity. It is well documented that turbidity in the lake is lower when salinities are higher and vice-versa. Any predictions regarding declining lake clarity must consider the overall salinity regime because years of high salinity and low turbidity can interrupt the apparent downward trend (Thompson and Fitzhugh, 1985). For example, DEQ measured turbidity in 1982 and 1983. In 1982, mean salinity at their stations was 6.2 ppt and the mean Secchi disc reading was about 100 cm, whereas in 1983, mean salinity was only 0.8 ppt and the mean Secchi disc reading was only about 50 cm. Mayer (1986) measured turbidity and salinity while conducting his study of the grassbeds. From May 24 through August, 1985, he measured turbidity and salinity at 80 nearshore stations in the lake. Mean salinity was 4.1 ppt and the mean Secchi disc reading was about 124 cm.

Although it is difficult to quantify the magnitude of turbidity changes in the lake, it appears to be the general consensus of those who have studied the lake that there has been an increase in average turbidity over the last 30 years.

Benthos

Numerous studies have been conducted concerning the benthic communities of Lakes Pontchartrain and Maurepas. The first substantial information concerning the benthos of Lake Pontchartrain was gathered during surveys conducted from 1953 to 1955. Darnell (1979, Unpublished Manuscript) has summarized this information. Sampling gear included otter trawls, bag seines, fine-meshed pushnets, and Peterson dredges. Sixty-seven species of benthic invertebrates were collected including sponges, coelenterates, ctenophorans, bryozoans, annelids, mollusks, and arthropods. The list could have been extended by looking at fouling

organisms, meiofauna, and the small inhabitants of grass beds and marshes (Darnell, 1979).

Sponges, hydroids, and ctenophores were each represented by a single species in the lake. Bryozoans were found encrusting dead shells of _Rangia cuneata_. Annelids encountered included leeches and polychaetes. Polychaetes were rare and usually taken in the eastern section of the lake, but occurred during all seasons. Arthropods represented in the benthic surveys included copepods, barnacles, mysids, isopods, amphipods, and decapod crustaceans. The most important decapod crustaceans included the blue crab and brown and white shrimp.

Mollusks constitute a very important component of the benthic community of the lake. _Rangia cuneata_ is the mollusk that primarily supports the shell dredging industry and is the subject of extensive discussion throughout this report. Two species of cephalopods (squid) were taken, generally in the more saline areas in the eastern sector of the lake. Five species of gastropods were encountered in Lake Pontchartrain. Two of these, _Melampus coffeus_ and _Neritinia reclivata_, were limited to the grass beds. One specimen of _Amnicola sp_. was found in the stomach of a blue catfish. The two remaining gastropods, _Probythinella louisianae_ and _Texadina sphinctostoma_ were widely distributed throughout the lake. Their numbers varied from 12.0 to 4,960/m2. _Texadina sphinctostoma_ was abundant at most stations and was particularly abundant at the more saline stations in the eastern portion of the lake, often numbering in the thousands/m2. It usually numbered in the hundreds/m2 in other portions of the lake. _Probythinella louisianae_, on the other hand, was uncommon at most of the saline stations and was abundant in the fresher portions of the lake.

Six species of pelecypods (bivalves) were found. Three of the species, _Angulus sybariticus_, _Crassostrea virginica_, and _Polymesoda caroliniana_, were very rare. _Brachiodontes recurvus_ appeared in the eastern sector of the lake. _Congeria leucopheata_, a small bivalve which attaches to the shells of _R. cuneata_, was found throughout the lake. The

dominant bivalve in most of the lake was _R. cuneata_; however, in this study, it was not recognized that small _Rangia_ can be confused with other small bivalves including _Macoma mitchelli_ and _Mulinia pontchartrainensis_. Therefore, the data in this study are only valid for adult _R. cuneata_ (>20 mm). No _R. cuneata_ were found in any of the samples from the eastern lobe of the lake (that area approximately between the present location of the I-10 twin bridges and Lake St. Catherine) and density was low along the more saline southern area of the lake. In most areas of the lake, densities of _R. cuneata_ larger than 20 mm were consistently above 100/m2 (Figure D-2).

Fairbanks (1963) investigated _R. cuneata_ populations in two limited areas in Lake Pontchartrain, one area on the northern shore of the lake between Point Platte and Big Point (6 stations) and one area on the southern shore between the IHNC and Little River (5 stations). Studies were conducted between February 1957 and September 1958. Quantitative benthic samples were collected with Ekman dredges. Additional information, including studies on gonadal development, were also obtained. Fairbanks reported that no clams less than 23.75 mm contained recognizable gametes and he suggested that clams larger than this represented potentially sexually mature adults.

Fairbanks estimated the density of adult clams from the north shore stations to be 24.54/m2. On the south shore the density was only 2.69/m2. The mean density for juveniles (<23.75 mm) from the north shore stations was 1,807.1/m2. On the south shore the mean density of juveniles was 1,887.5/m2. However, these numbers for the juveniles must be considered with caution. As noted by Darnell (1979), small _R. cuneata_ are very easily confused with small _M. mitchelli_ and _M. pontchartrainensis_, species also known to occur in fairly large numbers in the lake.

Other mollusks encountered by Fairbanks in the two study areas included _P. caroliniana_, _M. mitchelli_, _C. leucophaeta_, and _T._

sphinctostoma. Dead shells of B. recurvus and T. plebius were also found.

Tarver (1972) sampled R. cuneata populations with a modified eighteen-inch oyster dredge throughout Lakes Pontchartrain and Maurepas to determine their occurrence, distribution, and density. A total of 187 samples were taken from November 1, 1969 to November 31, 1970. Ninety-six percent of the samples contained R. cuneata. Catches ranged from 42 to 1,517/m2. Higher concentrations of R. cuneata were found around the edges of the lakes, with not many clams at the stations located more than a mile offshore. The highest concentrations in this study were found at a station in the southwestern corner of Lake Maurepas. Average catch for a three-minute tow of the dredge at this station was 557.4 clams, or 4.3 clams/m2. This station had the highest mean turbidity and lowest mean salinity of any station and the clams had a low mean height. The lowest average catch of 0.42 clams/m2 was at a station off South Point. This station had the highest mean salinity and the average clam height was the greatest. Rangia cuneata collected in the study ranged from 8 to 64 mm, with a mean height of 30.9 mm.

Tarver made several observations during the study. Few clams were collected from hard, sandy-bottomed areas. Higher numbers of clams were generally found where the substrata was a mixture of sand, mud, and remnants of vegetation. In such substrates, clams were sometimes so abundant that their growth seemed to be limited.

Dugas et al. (1974) sampled the molluscan communities of Lakes Pontchartrain and Maurepas between April 5, 1972 and July 12, 1972. The lakes were divided into 99 grids (Figure D-3). Two Peterson grab samples were taken from each grid for a total of 198 samples. Eight species of pelecypods and two species of gastropods were found. Pelecypods included R. cuneata, M. pontchartrainensis, M. mitchelli, B. recurvus, C. leucophaeta, P. caroliniana, Tagelus plebius, and Crassostrea virginica. The two species of gastropods were T. sphinctostoma and P. louisianae.

A total of 4,127 *R. cuneata* from 2 to 5 mm composed approximately 77 percent of the total *R. cuneata* catch in the study. *Rangia cuneata* of 2 to 5 mm were absent from the seven grids located in the eastern lobe of Lake Pontchartrain and the six grids in the western portion of Lake Maurepas. Dense populations of up to 1,847 clams/m2 occurred near the shoreline of Lake Pontchartrain. *Rangia cuneata* in the 6 to 10 mm size range were much less abundant than the 2 to 5 mm group, occurring in only 29 percent of the total samples. Again, they were notably absent from the eastern lobe of Lake Pontchartrain and in most of Lake Maurepas. They were also absent from many of the samples in southeastern Lake Pontchartrain where clams in the 2 to 5 mm range were encountered. *Rangia* in the 11 to 15 mm size range were scattered in distribution and not very abundant. Only 27 clams of this size were reported from 18 percent of the grids. Only one *Rangia cuneata* of this size was found in the sampling in Lake Maurepas. *Rangia cuneata* greater than 16 mm were not found in areas that had been continually dredged. They were most abundant in Lake Pontchartrain around the shorelines and were also absent from the eastern lobe of the lake. The highest densities of this size range were found in Lake Maurepas. In Lake Pontchartrain, the highest density of *Rangia cuneata* larger than 16 mm was found in a nearshore grid just west of the Bonnet Carre' Spillway, where 583 clams/m2 were collected. The highest density of the larger *Rangia cuneata* in Lake Maurepas was 820 clams/m2 near the mouth of the Tickfaw River.

Mulinia was the second most abundant mollusk, with a total of 3,787 collected. Only 7 percent of the samples in Lake Maurepas contained *Mulinia*, whereas it occurred in 95 percent of the Pontchartrain samples. It seemed to occur in highest concentrations near the southeastern shoreline of the lake.

Brachiodontes was taken mostly in the southeastern portions of the lake in areas where saltwater enters the lake. It was often found in association with oysters. *Congeria* was collected primarily in association with the periphery of Lake Pontchartrain with few being taken in mid-lake areas. They were not found in Lake Maurepas. *Tagelus* was

found in only three grids in the eastern portion of Lake Pontchartrain. These mollusks generally occur in higher salinities. *Polymesoda* was collected in a total of 25 grids in Lake Pontchartrain. It was absent from Lake Maurepas. The highest density was 66/m2 and occurred in the same grid in Lake Pontchartain as did the highest density of the *R. cuneata* larger than 16 mm. Substantial populations of *Crassostrea* are known to occur in eastern Lake Pontchartrain, although only two were taken in this study.

Of the two gastropods taken in the study, *T. sphinctostoma* was present in 89 percent of the samples taken in Lake Pontchartrain. None were taken in Lake Maurepas. Average density was 322/m2, with the highest density being 856/m2. *Probythinella louisianae* was also limited to Lake Pontchartrain. The average abundance was 139/m2. The highest densities of this species seemed to occur in areas influenced by freshwater input. They were not as common east of the Causeway and were totally absent from samples taken in the eastern lobe of the lake.

Tarver and Dugas (1973) sampled *R. cuneata* with a modified oyster dredge on a monthly basis at 15 stations throughout Lakes Pontchartrain and Maurepas. The dredge was towed for three minutes at a standard speed of 1,000 RPM. A total of 376 samples were taken over an approximate two-year period. The 15 stations were sampled from 23 to 28 times. When more than 100 clams were collected at a given station, a random selection of 100 clams were measured for size. A total of 80,644 *R. cuneata* were taken at the 15 stations, an average of 5,376 per station. Average catch per unit effort was about 211 clams, ranging from a low of 44.0 at a station located near South Point to a high of 412.7 at a station in Lake Maurepas near the mouth of the Blind River. Mean height of the clams measured was about 32.1 mm, ranging from a low of 27.1 mm to a high of 43.8 mm. Clams generally attained a larger mean size in areas where the catch per unit effort was lower.

No *R. cuneata* were taken in the extreme eastern lobe of Lake Pontchartrain, probably because this area approaches the upper salinity

tolerance limit for the clams in this system. Clams were particularly abundant near the shoreline and where tributaries enter the lakes. The highest densities of clams were found in the western portion of Lake Pontchartrain, and dense populations of clams were also found in Lake Maurepas. The highest catch per unit effort in the study was near the mouth of the Blind River. It was noted that R. cuneata populations decreased in density with increased water depth (Tarver and Dugas, 1974).

GSRI (1974) sampled benthos at 22 stations, 20 in Lake Pontchartrain and two in Lake Maurepas (Figure D-4). Eight Ekman dredge samples were taken at each station. They encountered most of the same mollusks collected in the previous studies. Dominant organisms included R. cuneata and two small gastropods. It appears, however, that one of the gastropods was misidentified in this study. They reported T. sphinctostoma, which is consistent with previous and subsequent studies, but instead of P. louisianae, which has been reported as the dominant gastropod in all of the other studies, the GSRI report identified the other gastropods as members of the family Amnicolidae, in particular Amnicola dalli. Amnicola is a freshwater genus, and although it could conceivably be found in fresher portions of the lakes area, it is not likely to be found in the salinities from which they were reportedly taken in this study. The gastropods reported as amnicolids in the study are assumed to be P. louisianae in this report.

The mean density of P. louisianae found at the 20 baseline stations in Lake Pontchartrain was 4,055/m2. Texadina sphinctostoma were found in a mean density of 776/m2 and R. cuneata occurred at an average density of 125/m2. The R. cuneata were not segregated according to size.

Bahr et al. (1980) conducted a macrobenthic survey of Lake Pontchartrain. The lake was divided into the same 86 grids used by Tarver and Dugas (1973), although only 85 were actually sampled. Due to certain constraints, monthly sampling was conducted at a total of 10 stations from within these 86 grids (Figure D-5). Benthic samples were collected with a J. and O. box core (Jonasson and Olausson, 1966), with

one core being taken in each grid. Replicate samples were taken at each fourth grid.

Twenty four species or related groups were collected at the 85 stations, with the six most abundant species comprising about 93 percent of the total. The average species diversity (Shannon-Wiener) for all of the samples collected was 1.37 ± 0.04. The size of the R. cuneata taken in the study varied considerably between the shoreline and the open lake. Shallow areas were dominated by large R. cuneata (>30 mm), whereas clams larger than 10 mm were very rare at the 85 open lake stations.

Roberts (1981) conducted studies of the benthic communities in Lake Pontchartrain using 10 stations along a transect in the northeastern portion of the lake (Figure D-6). The stations ran in a southwesterly direction from just north of Goose Point out into the restrictive corridor along the Causeway. A total of 23 macrofaunal taxa were found at the 10 stations. The dominant macrofauna were R. cuneata, M. pontchartrainensis, P. protera, T. sphinctostoma, and C. leucophaeta.

The largest R. cuneata found was 46 mm and was taken at station 10. No R. cuneata were taken between 10 and 42 mm in size. Clams larger than 42 mm were only found at stations 1, 2, and 5 (nearshore) and at station 10. Biomass of R. cuneata and P. protera demonstrated a gradual increase from stations 2, 3, and 4, peaking at station 5 (1.0 mile from shore), with a distinct drop at station 6 (1.25 miles from shore). Biomass of M. pontchartrainensis and T. sphinctostoma was lowest near shore, gradually increasing across the open lake, peaking at station 10.

Most of the Rangia and Mulinia taken during the study ranged from 2 to 5 mm. Biomass of Rangia was significantly greater than Mulinia at nearshore stations.

Fourteen taxa of meiofauna were taken during the study. Nematodes dominated at nearshore stations (1-5), but at stations 6-8 nematodes

declined and harpactocoid copepods became dominant. Nematodes dominated the meiobenthic fauna at stations 9 and 10.

Sikora et al. (1981) conducted a study concerning the environmental effects of clam shell dredging. The primary purpose of this study was to compare the sediments and benthic communities in a dredged and a control area. An experimental dredge station (DX) and a control station (DC) were selected in the protected corridor adjacent to the Lake Pontchartrain Causeway (Figure D-7). This area along the Causeway has been restricted from dredging since 1956. A shell dredge was used to conduct dredging activities at DX so that sediments and benthic communities could be compared between DX and DC over time. The results of this study are discussed in the benthic impacts section of the EIS. In order to assess the recovery of the benthic community over a longer period of time in the area examined by the Sikoras, an investigation was conducted to gather more information regarding the environment at stations DX and DC. Taylor Biological Company was hired to sample these stations in a manner consistent with that used by the Sikoras to ensure compatability of the data. Sampling was conducted on September 9 and 10 and November 12, 1986. Both sediment and benthic samples were collected. The primary purpose of the study was to resample the surface and bottom water, sediments, and macrobenthos at Sikora's DC and DX stations, and compare the resulting data to findings they presented from periodic sampling, before and after experimental shell dredging, between 1978 and 1981. Additional sediment sampling was also conducted in other areas of the lake to obtain additional values for bulk density and to record observations regarding the presence or absence of a "fluffy layer" at the sediment surface in freshly dredged areas and adjacent lake bottom. The results of this sampling have been statistically compared with data collected by the Sikoras and submitted to NOD in a January 28, 1987 report entitled "Shell Dredging Reevaluation and Sediment Study - Lake Pontchartrain, Louisiana." The results of this study have also been summarized in the benthic impact section of the EIS.

Sikora and Sikora (1982) characterized the benthic community of Lake Pontchartrain. The lake was divided into the same 86 grids used by Tarver and Dugas (1973) and Bahr et al. (1980). A preliminary sampling cruise was conducted on August 1, 1978 and regular sampling was conducted at various stations from August 16, 1978 through September 3, 1980.

The Sikoras conducted preliminary sampling and statistical analyses of the samples to determine the number of samples necessary to provide statistically meaningful information. Ten monthly stations and three stations to be sampled seasonally were established (Figure D-8). To sample macrofauna, three replicate samples were taken at the thirteen stations with a modified J. and O. box corer (0.09 m2). These were then subsampled for meiofauna taking four replicates from each core with acrylic core tubes (4.9 cm2).

Many differences were noted at different stations and, in many cases, the results were quite different between the two years of the study (1978-1979 and 1979-1980). Average macrofaunal abundance during the first year of the study was 22,665/m2 compared with 25,436/m2 for the second year. Macrofaunal abundance over the entire study period ranged from 11,228/m2 at station 1 to 39,141/m2 at station 13. Mollusks comprised about 95 percent of all organisms found. In the first year (1978-1979), T. sphinctostoma, averaging 11,869/m2, was dominant at nine stations, and P. louisianae, averaging 4,625/m2, dominated at the remaining four. In the second year of the study, numbers of T. sphinctostoma were similar to the first year, but numbers [illegible] louisianae more than doubled. Texadina sphinctostoma, [illegible] 10,070/m2, dominated at seven stations and P. louisianae, [illegible] 9,753/m2, dominated at five. Rangia cuneata demonst[illegible] reduction in numbers from an average of 3,794 m [illegible] 1,508/m2 the second year.

Species diversity for the macrofauna [illegible] 0.773 ± 0.051 to 1.374 ± 0.059. [illegible] The average number of species [illegible]

AD-A186 640 CLAM SHELL DREDGING IN LAKES PONTCHARTRAIN AND MAUREPAS 5/5
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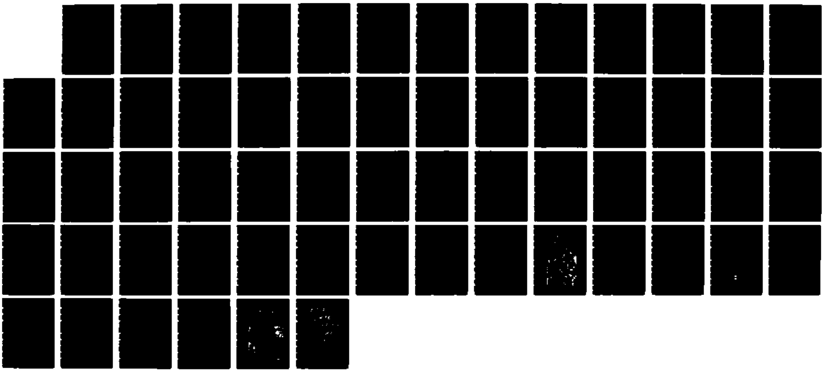

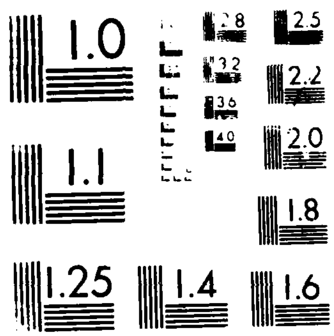

RESOLUTION TEST

from 9.308 ± 0.870 to 13.000 ± 0.476. There was no obvious pattern in variation of species diversity over the lake on a monthly basis. No noticeable increases in diversity were noted as a result of influx of migratory species or reproductive peaks. This seems to indicate that station location affected diversity more than when it was sampled (Sikora and Sikora, 1982). The percent occurrence (constancy) was noted for each species. *Texadina sphinctostoma* occurred in 100 percent of the samples. Chironomids ranked second with 98.9 percent constancy. *Rangia cuneata* was third in constancy, being taken in 98.45 percent of the samples. *Probythinella louisianae* was fourth at 96.39 percent.

The Sikoras stated that one of the most significant faunal changes in the lake was the loss of larger *R. cuneata* (>20 mm) from the open lake. They took 582 box core samples during their two-year study. Only 10 *R. cuneata* over 30 mm and 33 *R. cuneata* in the size range of 20-30 mm were collected in these samples, representing a mean density of 0.19/m2 and 0.62/m2, respectively. During the two-year period, the overall mean density for all sizes of *R. cuneata* was 3,256.5/m2; however, clams over 20 mm equaled less than 0.03 percent of the density. *Rangia cuneata* in the size range 10-20 mm accounted for less than one percent of the overall mean density.

Poirrier *et al*. (1984) evaluated the benthic community of southern Lake Pontchartrain (Figure D-9). Samples were collected by biologists from DEQ. One to five grabs were taken on a monthly basis at sixteen stations using a 6 in x 6 in Ponar dredge. A total of 207 samples were taken from March 1982 through March 1983.

Fifty-six taxa were collected during the study. The number of species found at a given station ranged from 0 at station LP06 in August to 23 at station LP02 in January. The average number of species for the 16 stations ranged from a low of 7 at LP08 to 17 at LP02. Average number of individuals per m2 for the 16 stations ranged from 480/m2 at LP08 to

12,096/m2 at LP14. The average number of organisms for all stations was 7,414/m2. The taxonomic composition of organisms collected at the monthly sampling stations showed considerable variation, but it was not possible to determine whether the temporal and spatial differences were due to population changes or chance variation as a result of sampling techniques.

Species diversities for the 12 monthly samples from the 16 stations were calculated using the Shannon-Weiner Index. The highest diversity was 2.527, with diversity values for all stations averaging 1.540. All stations had some samples with diversity values of 1.5 to 2.0. Benthic communities east of the causeway generally exhibited lower diversity and density than those west of the causeway and diversity and density were lower during summer months, demonstrating seasonal stress.

<u>Rangia cuneata</u> abundance was obtained for four size classes in this study (2-10, 10-20, 20-30, and >30 mm). As reported in the other studies, large numbers of small clams were found, with larger clams being far less abundant.

In this study, the number of gastropods was considerably lower than reported by Sikora and Sikora (1982). <u>Texadina sphinctostoma</u>, the most abundant gastropod in their study, was found in densities of 11,869/m2 and accounted for about 52 percent of the relative abundance of taxa. In this study, <u>T. sphinctostoma</u> averaged 1,214/m2, with station means ranging from 2.9 to 4,457/m2.

Childers (1985) conducted a baseline study of water quality and faunal communities in Lake Maurepas, including components of the macrofaunal community. Benthic samples were collected at stations 1-7 (Figure D-10) on five sampling dates using a Petite Ponar dredge. Five replicates were taken at each site. Sampling was conducted from October 1983 through September 1984.

A total of 21 taxa of invertebrates were identified. Rangia cuneata accounted for about 29 percent of the organisms. Six taxa made up 87 percent of the organisms counted. In addition to Rangia, chironomids, polychaetes, oligochaetes, and the hydrobiid gastropods P. louisianae and T. sphinctostoma contributed to this percentage. In general, these benthic organisms were more abundant at nearshore stations than in mid-lake. Organisms at mid-lake were not as numerous and were also represented by fewer species. Species diversity (Shannon-Weiner) averaged 1.34 for the year. Due to their relatively large size, Rangia dominated the biomass of the benthos. Clams were numerous at all of the nearshore stations, except for station 5. Few clams larger than 10 mm were found at this station. Clams were less abundant at stations 6 and 7. Very large clams were most abundant near the mouth of the Blind River where clams larger than 40 mm averaged 8/m2. An average of 205 clams/m2 larger than 20 mm were found at stations 1-4. Most clams collected at stations 5 and 6, and all clams collected at station 7 were less than 10 mm.

The two species of hydrobiid snails were widely distributed and occurred in substantial numbers throughout the year. Highest numbers of P. louisianae were collected at stations 2, 3, and 4, with few taken at station 1 and none at station 5. Texadina sphinctostoma was most abundant at station 5.

In order to discuss the impacts of shell dredging on benthos, it is necessary to describe the areal extent of bottom disturbance caused by dredging activities and to put these figures in perspective. Since the seven dredges currently used in Lake Pontchartrain are all slightly different, average figures are used in the following calculations. These calculations represent only the area directly impacted by passage of the fishmouth. As discussed in the EIS and Appendix C, additional areas

adjacent to the actual dredge cut are impacted by a thin layer of fluid mud, which may also destroy some benthic organisms.

Average speed of dredge = 1.92, or 2.0 miles per hour (mph) (based on analysis of LORAN C tapes)

2.0 mph x 5,280 ft/mi = 10,560 ft/hr x .3048 m/ft = 3,219 m/hr

5 ft (average width of trench) x .3048 m/ft = 1.524 m

3,219 m/hr x 1.524 m = 4,906 m2/hr

4,606 m2/hr x 18.5 hrs/day (average operating hrs/day) = 90,761 m2/day

90,761 m2/day x 7 dredges = 635,327 m2/day

Total area of lake (Swenson, 1980) = 1,630,000,000 m2

1,630,000,000 x .44 (percent open to dredging) = 717,000,000 m2

717,000,000 m2 / 635,327 m2 per day = 1,129 days to dredge permitted area

1,129 days/285 days (average operating days/yr) = 3.96, or 4.0 years to dredge permitted area

Therefore, it takes about 4.0 years for the dredges to disturb an area equivalent to the total permitted area in Lake Pontchartrain. In any given day, the dredges disturb an average of 0.039 percent of the total lake bottom (635,327 m2 per day / 1,630,000,000 m2 in Lake Pontchartrain).

Using the same basic methodology, the rate of disturbance of water bottoms for Lake Maurepas was calculated. The only changes made were in the number of dredges permitted in the lake at any given time (3) and the total area and permitted area of the lake.

90,761 m2/day x 3 dredges = 272,283 m2/day

Total area of lake = 93 mi2, or 240,861,012 m2

240,861,012 m2 x .58 (percent open to dredging) = 139,699,387 m2

139,699,387 m2 / 272,283 m2 per day = 513 days

513 days/285 days (average operating days per year) = 1.8 years to dredge permitted area

Therefore, it would take about 1.8 years for the dredges to disturb an area equivalent to the total permitted area in Lake Maurepas. In any given day, the dredges would disturb an average of 0.11 percent of the total lake bottom (272,283 m2 per day / 240,861,012 m2 in Lake Maurepas).

The above calculations show the area potentially affected by the dredges. It is important to note that these figures represent the area that can be covered. However, in actuality, it is probable that some bottom areas have been disturbed repeatedly, while others have been dredged less frequently, or possibly not at all. The dredges move continously in a circular pattern. The fishmouth is only several feet wide, whereas the dredges are about 40-45 feet wide. As the dredge circles, undredged areas likely occur between the roughly concentric rings. To complicate matters, the dredging zones and annual dredging schedules established by LDWF affect dredging intensity in any given area as well as the time interval between dredging events in any given area.

It appears that shell dredging is a fairly inefficient operation in terms of harvesting all of the shells from the area over which the fishmouth passes. If it were highly efficient, shells would not still be harvested in the quantities that they are today - they would have been harvested to a level below economic feasibility some years ago. However, it is apparent that the shell resource is declining and there is not any significant recruitment of large clams to the resource. Although beds of large, live Rangia are still encountered, the number of live clams harvested has decreased dramatically. In the 1930's, many live or dying large Rangia were reported on the barges and stockpiles and were known to emit foul odors due to a relatively large number of decomposing clams (Tarver, 1972). Fairly large numbers of live clams were still reported as late as the 1960's, but few live Rangia are observed in the stockpiles today. This decline of larger Rangia is further supported by the studies reviewed above. The shell dredging industry has estimated that the life of the industry, based on an average annual harvest of 3 million cubic yards, is about 17 to 25 years.

Several investigators have noted that perhaps the most dramatic change in the benthic community is the decline of larger Rangia in the open areas of Lake Pontchartrain where shell dredging is permitted (Tarver and Dugas, 1973; Dugas et al., 1974; Bahr et al., 1980; Sikora and Sikora, 1982). Numerous theories for this decline have been promulgated. The theory that seems most plausible has been discussed in the benthic impacts section of the EIS. The remaining theories are discussed below.

It has been suggested that shell dredging has caused the sediments to become softer and less stable (bulk densities have decreased), and, as a result, the large Rangia sink into the sediments and die. It is difficult to conclusively state whether or not this is a major factor.

However, based on recent field surveys and laboratory studies, some inferences can be made. In June, 1986, a sediment survey of five selected lakes in coastal Louisiana, including Lakes Pontchartrain, Borgne, Salvador, Palourde, and Little Lake, was sponsored by the Louisiana Shell Producers Association. Results of this survey are reported in a report by Steimle and Associates (1986). Core samples for bulk density analyses were collected by diving by Dr. John L. Taylor of Taylor Biological Company, Lynn Haven, Florida. Triplicate samples were taken from seven stations in Lake Pontchartrain and one set of triplicate samples was at a station in each of the other four lakes. Bulk density analyses were performed by Eustis Engineering, New Orleans, Louisiana.

The range and average of bulk densities for the seven Lake Pontchartrain stations and the single stations in each of the other four lakes is presented below.

Lake Name	Bulk Density Range (g/cc)	Bulk Density Average (g/cc)
Lake Pontchartrain	0.97-1.58	1.30
Lake Borgne	1.46-1.65	1.52
Lake Salvador	0.93-1.36	1.07
Little Lake	1.37-1.74	1.53
Lake Palourde	1.20-1.35	1.26

At the Lake Salvador station location (Figure D-11), Dr. Taylor collected 100 live <u>Rangia</u> for future laboratory studies. Shell height (lip to beak) of these clams ranged from 28-43 mm and shell length (end to end) ranged from 32-47 mm. Their weights ranged from 14.12-47.79 gms and averaged about 34 gms. These were all large, adult clams. The bulk densities for the three sediment samples taken at Station 8 in Lake Salvador are presented below.

Sample Depth Range (cm)	Average Bulk Density (g/cc)	Bulk Density Range (g/cc)
0-7	1.20	1.00-1.36
7-14	1.06	1.00-1.17
14-42	0.95	0.93-0.97

Decreased bulk densities with depth were related to organic content. It was obvious that the large Rangia flourished in this area at bulk densities ranging from 1.00 to 1.36 g/cc. Later on the same day, Dr. Taylor collected over 100 liters of sediment from Station 11 (Figure D-12) in Lake Pontchartrain to be used in clam survival tests using the live Rangia.

The tests performed by Dr. Taylor were designed to determine whether the Rangia collected in Lake Salvador could survive in the sediments collected from Lake Pontchartrain. Only one clam was lost in transit to Dr. Taylor's laboratory, leaving a total of 99 for laboratory testing. The clams were divided into three groups. Two groups contained 40 clams each and the third group consisted of the remaining 19 clams. The three groups of clams were placed on the sediment surface in three separate tanks containing 6 inches of sediment and allowed to burrow to their desired depth. Groups one and two were placed in tanks of 60 liter capacity, whereas group three, consisting of only 19 clams, was placed in a tank of 30-liter capacity. Survival was monitored on a weekly basis in all three tanks. At this time, water was changed in the tanks, the sediment was thoroughly mixed by hand, water of the proper salinity (6-8 ppt) was added, and the clams were once again allowed to burrow. All clams survived the first three weeks; two clams in one group and one clam in each of the other two groups died the fourth week, leaving a total of 95 remaining clams for additional testing. This testing demonstrated that the clams survived and maintained themselves well in the Lake

Pontchartrain sediments. Observations of the clams in all three tanks indicated that the clams burrowed into the sediment to a point where the posterior end was about one-half inch below the sediment surface. In this position, the clams created a shallow depression in the sediment above by jetting water upward from the excurrent siphon. This depression may act to collect much of the fine detrital material consumed by the clams.

A shallow burial test was then conducted. The 39 remaining clams in group one were again placed in their tank on the sediment surface and allowed to burrow, but the other 56 clams were placed in their respective tanks and pushed down to at least two inches beneath the surface of the sediment. After one week, all clams survived, even the ones covered by two inches of sediments. There was no indication that any of the clams moved or attempted to re-orient their position in the sediments. The depressions over the clams were once again observed.

A deep burial test was then conducted. The 19 clams in group three were placed in their tank on the sediment surface. Anticipating some mortality in this test, the other two groups were reduced to five clams each and placed in each corner and in the middle of the tank. The clams were pushed to the bottom of the tanks, which buried them in about six inches of sediment. After one week, all clams from all three tanks were removed. Group three, the control tank, contained two dead clams. In the other two tanks, only one clam survived. No depression was noted above the surviving clam. Rangia have been reported to withstand anoxic conditions (Chen and Awapara, 1969). Again, none of the clams, even the ones buried by six inches of sediment demonstrated any vertical or horizontal movement.

The bulk densities for the three sediment samples from Station 11 in Lake Pontchartrain are presented below. Bulk densities from the other six stations sampled in Lake Pontchartrain are also provided to demonstrate the similarity of the data for the stations.

Station Number	Sample Depth Range (cm)	Average Bulk Density (g/cc)	Bulk Density Range (g/cc)
11	0-8	1.27	1.08-1.38
	8-14	1.39	1.28-1.50
	14-55	1.30	1.25-1.33
1	0-9	1.27	0.97-1.53
	9-15	1.34	1.28-1.38
	15-55	1.33	1.31-1.37
2	0-7	1.26	2 samples taken both 1.26
	7-14	1.26	1.24-1.28
	14-55	1.26	1.24-1.28
3	0-6	1.35	1.32-1.40
	6-13	1.42	1.39-1.47
	13-54	1.40	1.35-1.44
4	0-9	1.31	1.26-1.35
	9-16	1.37	1.35-1.39
	16-58	1.23	1.22-1.24
5	0-7	1.15	1.03-1.27
	7-13	1.35	1.21-1.58
	13.58	1.23	1.22-1.24
6	0-8	1.32	1.30-1.33
	8-16	1.24	1.14-1.31
	16-54	1.27	1.26-1.28

Based on these tests, it appears that the clams survived well and were able to maintain their position in the Pontchartrain sediments. There was no evidence of sinking, and the clams were able to make position adjustments near the sediment surface. Survival of the clams in two inches of sediments indicates an ability to withstand some sedimentation. Their creation of depressions at this depth indicates that they could likely survive at this depth for prolonged periods. Results of these tests indicate that Rangia cannot survive deep burial for very long. They have short siphons and appear to have limited migratory abilities.

The longevity displayed by the clams in this study would seem to indicate that the Pontchartrain sediments from Station 11 did not exert any toxic effects on the Rangia, nor was there any evidence of the clams sinking in the sediments.

Although the results of the above tests are not conclusive, the information is a significant addition to that previously available. The fact that large Rangia survive in Lake Salvador in sediments with relatively low bulk densities and responded favorably in the test sediments from Lake Pontchartrain decreases the viability of the theory that the large clams in Lake Pontchartrain are limited due to alterations in the bulk densities of the sediments. It is acknowledged, however, that the behavior of the sediments in the laboratory tanks is not necessarily the same as the sediments on the natural lake bottom. Under natural conditions, the sediments are subject to periodic movement and resuspension by wind and wave action, whereas the sediments in the tanks would tend to be more stable.

Taylor (1987) sampled sediments during his investigation of the benthic communities at stations DC and DX in Lake Pontchartrain. Sediment samples were also taken in several other locations in the lake immediately after dredging and one week after dredging. The purpose of this sampling was to obtain additional values for bulk density and to record observations regarding the presence or absence of a "fluffy layer"

at the sediment surface in freshly dredged areas and adjacent lake bottom. Dr. Taylor concluded that the bulk density of the bottom is altered by dredging at a specific location, but overall, shell dredging apparently has no long-term effect on bulk density in Lake Pontchartrain. In that study, it appeared that bulk density returned no normal shortly after dredging. With regard to the so called "fluffy layer," no such layer was ever observed at any station during the investigation.

The issue of fluid mud generated by shell dredging activities has been discussed in several areas of this document. Some of the impacts of fluid mud on benthic organisms are discussed here.

Diaz and Boesch (1977) reported on the impact of fluid mud dredged material in the tidal James River. They found that, in areas receiving less than about 1 foot of fluid mud, acute effects were felt primarily by insects and small Asiatic clams. The clams declined in abundance, except in areas that received less than 0.1 m (about 4 inches) of fluid mud. The fluid mud presented support problems for these relatively dense organisms. Within a few weeks, however, most of these species including the clams had recolonized the site to predredging levels. It should be emphasized, however, that the time required for repopulation of Asiatic clams and *Rangia* are not comparable. As discussed previously, extended periods of time are required for establishment of populations of large *Rangia* in Lake Pontchartrain, even without fluid mud impacts.

In terms of its benthic community impact, fluid mud is regarded as intermediate between turbidity and burial by more consolidated sediments. Unlike turbidity whose movement is controlled by local currents, fluid mud movement is controlled by gravity and tidal currents. Fluid mud begins to form at a concentration of 10 g/l and continues to be capable of fluid movement at concentrations up to 175 g/l, when consolidation begins (Barnard, 1978). Nichols *et al*. (1978) found that the fluid mud produced from disposed dredged material in the tidal James River was very persistent, with slow reconsolidation rates.

This tendency allowed the mud to spread over a larger area, and made it less capable of supporting dense organisms such as clams than more consolidated material.

Such organisms, dependent on contact with the overlying water, may not be able to survive unless they can reestablish contact, i.e., reach the fluid mud surface before being overcome by the stresses of physical burial. Although severe dissolved oxygen depression in the referenced fluid mud sediments was short-lived, it probably contributed somewhat to total organism destruction because of its additive effect to the stresses imposed by burial.

Another reason that has been suggested for the demise of the larger clams is that resuspended sediments silt up and choke the clams. It is possible that this is a factor; however, it must be remembered that Rangia have evolved and thrive in the upper portions of estuaries subject to periodic high concentrations of sediments from riverine input and are able to tolerate periodic elevations in concentrations of suspended sediments. Additionally, resuspension of sediments in Lake Pontchartrain by wind and waves is common. Darnell (1958) noted that Rangia are most abundant on the muddiest bottoms in waters of high turbidity. Although the concentrations of suspended sediments in the vicinity of a dredge are much higher than those from riverine input, they are also of much shorter duration. The clams could close their valves until the concentrations of sediments diminish. The depth of burial due to high concentrations of sediments, as discussed above, would likely be of greater significance. It should be pointed out that impacts of suspended sediments would not be limited to large Rangia - smaller clams would be impacted as well.

It has also been suggested that overall primary production in Lake Pontchartrain has decreased to a point that the lake cannot support a lakewide population of large Rangia. Although sufficient data do not exist to document reduced primary productivity, it is likely that it has decreased. Reduction in acreage of the grassbeds and adjacent wetlands,

as well as a possible decrease in phytoplankton production due the apparent long-term increase in turbidity, have conceivably caused a decrease in overall primary productivity. The increase in turbidity is the primary factor in which shell dredging is implicated. Sikora and Sikora (1982) reported that the organic content of the sediments has declined based on carbon content found in their study and that reported by Bahr et al. (1980) as compared with that reported by Steinmayer (1939). This would be an indication of decreased primary productivity. However, it is not known whether the techniques used by Steinmeyer allow comparison with more recent data.

The remaining theory to be discussed here for the disappearance of the large Rangia in the open lake concerns the presence of contaminants in the sediments and their potential for release by shell dredging activities. Section 3.4.2 and Appendix C discusses the contaminants present in Lake Pontchartrain sediments and the potential for release of these contaminants by dredging activities. With regard to disappearance of the large Rangia, perhaps the most important observation regarding contaminants in the sediments is that the highest concentrations of contaminants are found nearshore, particularly near the mouths of outfall canals and natural tributaries. Contaminant concentrations in the sediments tend to decrease with distance offshore. High levels of contaminants do not appear to be a significant problem in most areas of the lake open to shell dredging. Additionally, as discussed earlier in this benthos section, the most dense populations of both large and small Rangia are typically found in nearshore areas, particularly where sources of fresh water and nutrients enter the lake. The fact that the clams survive better in the more contaminated nearshore areas does not lend much support for contaminants being a primary factor in the disappearance of large Rangia in the open lake.

Regardless of which factor, or combination of factors, has caused the dramatic reduction in abundance of large Rangia, the significance of this reduction to the overall productivity of the lake is unclear. Rangia are consumed by a variety of organisms including fishes, invertebrates, and

wildlife. However, most organisms prefer the smaller size classes of Rangia (<5 mm and 5-10 mm), and small Rangia are still relatively abundant, even in many areas of the open lake.

The remainder of the benthic impact discussion concentrates on organisms other than Rangia. Of particular interest are two species of hydrobiid gastropods, T. sphinctostoma and P. louisianae. Although they have consistently been reported in abundance since the earliest studies in the lake, they have apparently increased in abundance as the large Rangia have decreased. This is not surprising for opportunistic species such as these hydrobiids. They can populate an area very rapidly. Heard (1979) observed P. louisianae in glass culture bowls in the laboratory and noted that the eggs hatched after 8-12 days of development. The small juvenile snails had a fully formed protobranch (shell) and began to crawl about on the sediments and begin feeding. T. sphinctostoma is also known to repopulate very rapidly, and due to its motile veliger stage, is able to travel further distances. Based on this information, it is easy to see how these small snails are able to repopulate dredged areas very rapidly. Hydrobiid gastropods occur in very high numbers in certain estuaries in this country, as well as in Europe and Africa. Walters and Wharfe (1980) reported an average of 90,000/m2 from 1969-1975 in the Lower Medway Estuary. The same study reported 663,000/m2 in the Danish Waddensee.

Darnell reported these organsims, but did not quantify their numbers. Solem (1961) independently analyzed Darnell's benthic samples and estimated densities of 4,093/m2. Sikora and Sikora (1982) reported densities of hydrobiids ranging from 15,000-20,000/m2 for their two years of study. However, Poirrier et al. (1984) reported far fewer gastropods in their study. Texadina sphinctostoma occurred in average densities of 11,869/m2 in Sikora and Sikora's study. Poirrier et al. (1984) found an average of only 1,214/m2, with the highest station mean being 4,457/m2. The reason for these differences is not clear, although it may be due to the fact that the Sikoras sampled more open-lake stations and sampled on a more lakewide basis. Taylor (1987) collected benthic samples at

Sikora's DX and DC stations on September 9, 1986 and found hydrobiids at densities of 6,710/m2 and 3,998/m2, respectively.

These hydrobiids are only about 2-3 mm at maturity and are thought to represent a loss of benthic biomass in the lake (Sikora and Sikora, 1982). The Sikoras estimated that Rangia biomass from Darnell's survey ranged from 20-50 g/m2. Estimates of macrofaunal biomass from their benthic sampling in 1978-79 and 1979-80 were 9.1 g/m2 and 7.9 g/m2, respectively. These estimates include large and small Rangia, the hydrobiids, and other macrofauna. The significance of this apparent decrease in benthic biomass is not well understood. It is not known if production of fishery resources in Lake Pontchartrain is directly related to benthic biomass. Other factors are involved. For example, large Rangia are consumed by relatively few organisms, so the biomass represented by the larger clams may not be of high value, although it is acknowledged that when the large clams die, their remains ultimately contribute to the overall productivity of the ecosystem. The average life span of adult Rangia is about 4 to 5 years (Lasalle and de la Cruz, 1985) and Hopkins et al. (1973) estimated the maximum life span of Rangia to be about 15 years. Therefore, it would appear that these large clams are not of primary importance as a direct food source; however, their fecal production may play an important role in the overall food web. Heard (1970) reported that P. louisianae and T. sphinctostoma also play an important role in the reworking and enrichment of the sediments. They consume a considerable amount of bottom material and produce large numbers of fecal pellets. The importance of fecal material and its probable role in the food web have been discussed and documented by Newell (1965), Johannes and Satomi (1966), Frankenberg et al. (1967), and Kraeuter (1976).

As evidenced by the preceding discussions, the reduction in populations of large Rangia and the apparent increase in numbers of the hydrobiid gastropods has been the subject of considerable interest in the literature. Numerous other groups of organisms also comprise important components of the benthic community. These organisms include other

bivalves (Mulinia, Macoma), copepods, amphipods, mysids, small crabs, chironomids, nematodes, oligochaetes, polychaetes, and others. Populations of these organisms have also been studied in the lake. Many of these organisms are also very opportunistic and can populate areas quite rapidly under proper conditions. Populations of these organisms are often highly seasonal, localized, and sporadic, making quantitative comparisons difficult. However, many of these organisms are very prolific and are probably able to repopulate areas disturbed by shell dredging in a matter of weeks. Those with motile larval stages are able to repopulate distant areas more rapidly. Those organisms without motile larval stages are able to repopulate adjacent areas rapidly, but take longer time periods to repopulate distant areas.

Nonetheless, it appears that even the populations of some of the opportunistic organisms including the hydrobiids, is influenced by dredging activity. Roberts (1981) conducted an interesting study, although it was unfortunately limited in scope. Roberts sampled benthic biomass and metabolism at the stations shown in Figure D-6. Benthic samples were taken every 0.25 miles along a transect from the shoreline out to 1.25 miles. Stations 1-4 were inside of the one-mile restricted zone, station 5 was located on the one-mile line, stations 6, 7, and 8 were in the open-lake area open to dredging, and stations 9 and 10 were in the restricted corridor along the Lake Pontchartrain Causeway.

Peaks of macrofaunal biomass, organic carbon content, and total community metabolism at station 5 dropped sharply to low values at station 6. The ratio of large to small shell fractions dropped sharply between these two stations as well. Nematodes dominated the meiofauna at stations 1-5, whereas copepods were dominant at stations 6, 7, and 8. Dominant macrofauna at the nearshore stations 2-5 were Rangia and P. louisianae, while at the open-lake stations 6-8, macrofauna was dominated by Mulinia pontchartrainensis and T. sphinctostoma. Roberts reported that these changes in dominance may be related to the life histories of the organisms. Mulinia may be more opportunistic than Rangia. Taylor et al. (1970) reported that Mulinia lateralis, a species very similar to

the species in Lake Pontchartrain, was an indicator of environmental stress in Hillsborough Bay, Florida. Mulinia does not reach as large a size as Rangia and probably reaches sexual maturity at a smaller size. In Robert's study, live, mature Rangia were only found near shore and at station 10 near the Causeway. The differences in abundance of the two gastropods may also be due to differences in their life cycles. *P. louisianae* does not have a motile veliger stage, whereas *T. sphinctostoma* has a motile veliger and is able to repopulate disturbed areas in the open lake more readily.

Changes in dominance were also observed between the open-lake stations 6, 7, and 8 and stations 9 and 10 near the Causeway. Macrofaunal biomass, community metabolism, and the shell ratio rose at stations 9 and 10, and, once again, nematodes replaced copepods as the dominant meiofaunal taxon.

The concept of the transect used in this study is very interesting. Unfortunately, the subject study was somewhat limited in scope. The distinctions between the restricted areas and the areas open to shell dredging were apparently rather sharp; however, in order to determine the role of shell dredging in these distinctions, it would be necessary to know the dredging history in the open water areas of the study area. It would also be dependent on the assumption that the one-mile restricted zone was adhered to very strictly.

Several investigators have calculated species diversity for the benthic community in the lake. Bahr *et al.* (1980) reported overall species diversity during an initial survey of 86 stations to be 1.37. Sikora and Sikora (1982) reported mean station diversities ranging from 0.773 to 1.249, with a mean of 1.089. Junot *et al.* (1983) reported values ranging from 0.239 to 1.591, with a mean of 1.042. Poirrier *et al.* (1984) reported mean station diversities ranging from 1.063 to 2.030, with a mean for all samples of 1.538. Taylor calculated species diversities of 1.48 for station DC and 1.38 for station DX from samples collected on September 9, 1986.

Several investigators have reported that species diversities in the range described above are generally indicative of an unhealthy, stressed environment (Bahr et al., 1980; Sikora and Sikora, 1982). Bahr et al., (1980) reported, based on their survey, that the macrobenthic community, at least in the open lake, is in poor condition and it is believed that this condition represents a historical decline. They hypothesize that the change in "health" of the benthic community coincided with the gradual increase in cultural perturbations affecting the lake. However, a major problem acknowledged by these and other investigators is the total lack of data on the lake prior to the time that most of the perturbations, including shell dredging, began affecting the lake ecosystem.

Fisheries

Lake Pontchartrain functions as a nursery and feeding area for many fresh water, estuarine, estuarine-dependent, and marine species. The fishery community is dominated by transient species that move into the lake for periods of several months and then emigrate back out to the gulf. There are distinct, seasonally grouped species that utilize the lake habitat depending upon various physical (temperature, turbidity, tidal range, and bottom topography) and chemical (salinity and nutrients) conditions which exist in a particular season. These fish species can be further distinguished by the amount of time spent in the lake. As noted by Thompson and Verret (1980), species can be grouped as periodic, resident, or occasional components of the population, based on the time spent in the lake. The population is dominated by the semiresident estuarine species component comprised primarily of the bay anchovy (Anchoa mitchilli), gulf menhaden (Brevoortia patronus), and Atlantic croaker (Micropogonius undulatus). These species live in the lake all year, but have certain portions of their population entering or leaving the lake at all times of the year. These species comprise about 80 percent of the fish population (Thompson and Verret, 1980). Based on habitat preference, approximately 55 species utilize the open lake, 22 species utilize the marsh, and 8 species are resident to both areas.

Fish species found only in the marsh are primarily fresh water and euryhaline.

The freshwater component is also mostly seasonal, with blue catfish (_Ictalurus furcatus_) becoming more abundant during cooler, less saline periods. The blue catfish move into Lake Maurepas and the tributary rivers with high salinity and increasing temperatures of late spring and summer (Thompson and Verret, 1980).

In general, the fish population in the lake increases in the spring, reaches maximum numbers in July, and gradually declines through late summer and fall. Eight of the 20 most abundant fish species (Table D-1) utilize the lake area, while the remaining 12 use the marsh. The forage base species such as croakers and anchovies utilize the open water areas of the lake from spring through fall. However, anchovies utilize the marsh as well as the lake. Juvenile menhaden are predominant users of the beach and marsh; however, as they become larger they move to the more open waters of the lake.

Darnell (1958) reported two major food chains in the lake. The first is based upon six major groups of benthic species including polychaete worms, mollusks, chironomids, isopods, amphipods, and xanthid crabs. The dominant species of benthos in the lake today are two small gastropods, _T. sphinctostoma_ and _P. louisianae_. These two species comprise a large percentage of the benthic community in the lake. Brackish water clams, _R. cuneata_, are also abundant and heavily utilized as food by some demersal species (Sikora and Sikora, 1982). The second chain consists of planktonic and nektonic food organisms associated with the water column including mysids, copepods, decapods, and fish.

A total of 129 species of fish representing 55 families have been reported from Lake Pontchartrain (Thompson and Fitzhugh, 1985). Freshwater species, fish that spawn primarily in fresh water and that have a tolerance for moderate salinities, account for 43 of the species. Estuarine species, fish that generally spawn and spend most of their life

TABLE D-1

THE 20 MOST ABUNDANT FISH SPECIES IN LAKE PONTCHARTRAIN AND SURROUNDING MARSH BY OVERALL HABITAT PREFERENCE

(Based on 1978 Data)

Common Name	Scientific Name	Open Lake	Grassbeds	Beach	Marsh
Bay anchovy	*Anchoa mitchilli*	1		2	2
Atlantic croaker	*Micropogonias undulatus*	1			
Gulf menhaden	*Brevoortia patronus*	1		2j	2j
Tidewater silverside	*Menidia beryllina*			2j	2j
Sheepshead minnow	*Cyprinodon variegatus*			2	1
Rainwater killifish	*Lucania parva*		2		1
Sailfin molly	*Poecilia latipinna*		2		1
Gulf pipefish	*Syngnathus scovelli*		1		
Spot	*Leiostomus xanthurus*	1	2j 1/		
Mosquito fish	*Gambusia affinis*				1
Gulf killifish	*Fundulus grandis*			1	2
Sea catfish	*Arius felis*	1		2j	
Striped mullet	*Mugil cephalus*	1		2j	
Spotted sunfish	*Lepomis punctatus*		2		1
Bluegill	*Lepomis macrochirus*		2		1
Sand seatrout	*Cynoscion arenarius*	1			
Blue catfish	*Ictalurus furcatus*	1			
Redear sunfish	*Lepomis microlophus*		2		1
Least killifish	*Heterandria formosa*				1
Naked goby	*Gobiosoma bosci*		1		

cycle within the estuary, account for 21 of the species. Estuarine-marine (estuarine-dependent) species, fish that spend a portion of their life cycle, primarily as young-of-the-year, in the estuary account for 26 of the species. Marine species, fish that spawn and generally spend most of their life in high-salinity waters, but sometimes enter the lower-salinity estuaries, account for 39 of the species that have been reported from the lake.

Although species that are considered fresh water and marine comprise the largest numbers of species recorded from the lake, the migratory, estuarine-dependent fishes clearly dominate the numbers of individuals found in the lake. During five years of fish sampling with trawls and seines conducted between the years 1953 and 1978, Atlantic croaker, bay anchovy, spot (*Leiostomus xanthurus*), gulf menhaden, sea catfish (*Arius felis*), and sand seatrout (*Cynoscion arenarius*) dominated the catch (Thompson and Fitzhugh, 1985).

Truly estuarine species that spend their entire life in the lake comprise an important component of the nearshore fish fauna. The inland silverside (*Menidia beryllina*), gulf pipefish (*Syngnathus scovelli*), gulf killifish (*Fundulus grandis*), sheepshead minnow (*Cyprinodon variegatus*), and rainwater killifish (*Lucania parva*) have dominated the nearshore catch over the 25-year period. The demersal fishes of the lake have been extensively studied between 1953 and 1978, with more than 850 trawls being taken. Although the methods were not identical, the sampling regime was consistent enough for comparisons (Thompson and Fitzhugh, 1985). These authors have reviewed and discussed these studies, and much of the information in this section is based on their report.

The first substantial fish sampling in Lake Pontchartrain was by Suttkus *et al*. from 1953-1955. In 1953-1954, a total of 44 species of fish were collected. The monthly top ten most abundant fish over the twelve month period contained 29 species. The bay anchovy and Atlantic croaker were considered to be very abundant, with blue catfish, hogchoker (*Trinectes maculatus*), gulf menhaden, spot, sea catfish, and

sand seatrout considered common. The other 21 species were considered uncommon to rare in occurrence.

During 1954-1955, a total of 60 species were collected. The monthly top ten fish consisted of 28 species. The bay anchovy and Atlantic croaker were again very abundant, with the gulf menhaden, spot, sea catfish, sand seatrout, and hogchoker being common. Due to higher salinities, the blue catfish was not as common as in the previous year. Thirty-two of the 60 species were considered to be very rare.

Tarver and Savoie (1976) reported on fishes collected from 1972-1974. During 1972-1973, a total of 33 species of fishes were collected. The monthly top ten fish consisted of 28 species. The bay anchovy and Atlantic croaker were the most abundant species, but croaker had declined from the previous surveys conducted in the 1950's. The lined sole (_Achirus lineatus_) and the hogchoker were considered common. Gulf menhaden, spot, sand seatrout, and blue catfish declined in abundance from the previous studies. Only four of the species taken during this period were considered rare.

In 1973-1974, a total of 27 species were collected, with the monthly top ten containing 26 species. The skilletfish (_Gobiesox strumosus_) was the only fish considered rare. The bay anchovy and Atlantic croaker were again clearly the dominant species. Five species were considered common. Blue catiish increased in abundance over the previous year and spot abundance remained lower than in the 1950's.

Thompson and Verret (1980) reported on sampling conducted in 1978. A total of 33 species were collected, with the monthly top ten containing 27 species. As in previous studies, the bay anchovy and Atlantic croaker were very abundant. The six species classified as common from the 1978 sampling were the same as in 1953-1954 and included blue catfish, hogchoker, lined sole, gulf menhaden, sand seatrout, and spot. Six of the 27 species taken in 1978 were considered very rare.

Based on analysis of the data collected between 1953 and 1978, Thompson and Fitzhugh (1985) have noted some changes in the overall fishery community of the lake, including changes in abundance and frequency of occurrence.

The bay anchovy was consistently the most abundant and frequently caught species. The Atlantic croaker consistently ranked second in frequency and abundance. Although it declined during certain periods (e.g., during openings of the Bonnet Carre' Spillway) it appears that their overall position in the community has not changed substantially over the 25 years of study. The sand seatrout remained a common member of the fish community, but exhibited a strong decline in frequency of occurrence. This species uses open waters of the lake as a nursery area and their diminished role in the fish community is due to impacts on this habitat (Thompson and Fitzhugh, 1985). The hogchoker remained a common member of the community, but also declined in frequency of occurrence and abundance. According to Thompson and Fitzhugh (1985), the hogchoker appears to complete its life cycle in the lake and stress in the open water habitat has diminished its role in the community. The blue catfish has varied in frequency of occurrence and abundance over the years but this is likely due to variations in the overall salinity regime during the years the samples were collected. It is well known that blue catfish are more abundant in the lake when salinities are lower.

Thompson and Fitzhugh (1985) also noted changes and common trends for other species, particularly some of the benthic-oriented fishes, including hogchoker, spot, bay whiff (Citharichthys spilopterus), southern flounder (Paralichthys lethostigma), and lined sole. The lined sole, which ranged from rare to common in the 1950's, was not collected from the lake in the 1978 surveys. All of these demersal fishes exhibited declines in abundance and frequency of occurrence over the 25-year period. Sand seatrout have demonstrated a similar decline. Deteriorating benthic conditions in the deeper, open-lake areas may provide a logical explanation for the common decline of these species (Thompson and Fitzhugh, 1985).

There appears to have been a decline in total species diversity of the demersal fish assemblage over the period of study. During the 1953-1955 sampling, monthly totals were commonly comprised of over 20 species, with several months having 25 to 39 species taken. In the 1972-1974 studies, monthly totals were consistently less than 20. In 1978, the average monthly total was only 13 species.

Childers (1985) reported on the fishes of Lake Maurepas. Fishes were collected with trawls, gillnets, and shoreline rotenone samples at 7 stations from September 1983 to September 1984. A total of 67 species of fish were collected. Ten species accounted for about 97 percent of the catch, with the bay anchovy comprising 69 percent. Nine species of fish were captured by all sampling methods and included gulf menhaden, blue catfish, channel catfish, gulf pipefish, freshwater drum (Aplodinotus grunniens), Atlantic croaker, striped mullet (Mugil cephalus), yellow bass (Morone mississippiensis), and Atlantic needlefish (Strongylura marina). Shoreline rotenone samples contributed 23 species not captured by the other methods, 10 species were exclusive to the gill net, and 3 species were exclusive to trawl catches.

Five species of invertebrates were collected during the fish sampling, including Macrobrachium ohione (freshwater shrimp), Callinectes sapidus (blue crab), Palaemonetes pugio (grass shrimp), Penaeus setiferus (white shrimp), and Rithropanopeus harrisii (mud crab).

The preceding discussion addresses primarily those organisms important from an overall ecological and food base standpoint and included the twenty most abundant fish species. The importance of these organisms cannot be over emphasized, because the lake is important as a nursery area for many species. Of special concern to many people, however, are harvestable size commercial and recreational species.

The following discussion addresses the major commercial fisheries resources in the lake. Harvest data described in the following paragraphs are from the National Marine Fisheries Service (NMFS). The

figures do not include harvest by recreational fishermen, nor do they include all of the harvest by commercial fishermen. A prime example is the blue crab fishery in the lake. Roberts (1981) conducted a study of the commercial blue crab fishery. Based on extensive interviews, he determined that the actual blue crab harvest from the lake may be as much a 6 times the reported catch. Therefore, NMFS statistics do not show the total fishing pressure on the lake. It appears that a large percentage of the fishery harvest from the lake is sold directly to individuals and restaurants and therefore is not recorded in the NMFS statistics.

Thompson and Stone (1980) discussed the NMFS data for Lakes Maurepas and Pontchartrain from 1963-1975. Crabs, shrimp and catfish comprised the bulk of the commercial fishery. During this 13-year period, Lakes Pontchartrain and Maurepas accounted for about 9 percent of Louisiana's crab harvest and 0.13 and 0.10 percent of the state's shrimp and fish harvest.

The blue crab dominated the catch. During the 13-year period of 1963-1975, blue crab accounted for, on the average, 67 percent of the value and 79 percent of the volume of Lake Pontchartrain's catch. During this period, the harvest of blue crabs far exceeded the other fishery resources. The catch ranged from 325,800 to 2,028,300 pounds and averaged about 807 thousand pounds. The total catch for the 13-year period was about 10.5 million pounds, valued at $1.7 million. Shrimp and fishes accounted for 19 and 14 percent of the value and 10 percent each of the volume of the lake's catch. The shrimp fishery in Lake Pontchartrain includes both brown and white shrimp. Brown shrimp prefer higher salinities and are found in the lake in greatest abundance in dry years. White shrimp prefer lower salinities and were historically found in greater abundance in Lake Pontchartrain. Commercial finfishing in the lake is dominated overall by catfish and spotted seatrout. Between 1963 and 1975, catfish dominated the catch 11 out of 13 years. Both channel catfish and blue catfish are harvested. These species are facultative invaders of brackish water, but have a limited ability to live in brackish waters (Thompson and Stone, 1980).

Thompson and Fitzhugh (1985) summarized commercial fishery data for Lakes Pontchartrain and Borgne for the period of 1976-1983. Due to changes in the methods by which NMFS collects their statistics, it was not possible to obtain data just for Lake Pontchartrain.

The blue crab remained the dominant commercial species. During this 8-year period, blue crab accounted for 16 percent of the volume of the catch from the lakes. The harvest ranged from a low of 1,249,805 pounds to a high of 2,800,127 pounds, with an average of about 1.8 million pounds. The total catch for the 8-year period was about 14.4 million pounds valued at about $0.5 million. The total shrimp harvest was 5,867,652 pounds and averaged about about 733 thousand pounds per year. Total value of these shrimp was about $10.2 million. The shrimp harvest accounted for about 21 percent of the total poundage of commercial fish harvested from the lake and about 41 percent of the value. The noticeable fluctuations in the shrimp catch on a year by year basis are probably due to varying salinity conditions. Finfish harvest ranged from 30,805 pounds to 423,324 pounds, with catfish dominating the catch.

Increased levels of turbidity and suspended solids due to shell dredging activities has been discussed in detail in section 3.4.2 and Appendix C. In nature, fish are often exposed to a range of environmental conditions from temperature and dissolved oxygen fluctuations as well as increased turbidity, and the tolerance of such conditions varies with species, developmental stage, duration and severity of exposure as well as with other factors. Exposure to conditions outside the normal range can often be tolerated for short periods of time. However, the effects of chronic exposure of populations are uncertain (Cairns, 1968 and Stern and Stickle, 1978). The abundance of a fish population is determined by the birth rate which is a function of the percentage of mature fish, fecundity and fertility, the death rate which is specific for each life history stage, and immigration and emigration into the area (McFadden, 1976). It may be important, particularly in an open system such as Lake Pontchartrain, to identify any fish stocks or subpopulations which may be exposed to a particular

localized environmental condition and to differentiate these stocks of the same species (McFadden, 1976). A reduction in the reproductive capacity of a species, either through elimination of spawning sites or reduced survival of eggs, larvae, or juveniles can have a serious effect on a population (Ricker, 1945; Sherk, 1971; McFadden, 1976; Morton, 1977).

Sensitivity of a population to impact imposed by an environmental stress such as dredging will depend on the age classes affected and duration, as well as intrinsic features of the population and the biological productivity and stability of the environment (McFadden 1976, 1977).

Impacts of shell dredging on fish populations due to suspended sediments may include siltation of spawning areas affecting developmental and hatching success; reduction in light penetration and associated decrease in productivity; as well as reduction of efficiency of visual feeders; alteration of natural movements, behavior, or migrations; direct effects on gill tissue; and reduced food availability. Behavioral responses of fish to quantities of suspended sediments range from such specific responses as air-gulping, coughing, and scraping of body surfaces, to general increases or decreases in activity. Responses vary with species and specific experimental conditions. Reduced visibility may affect discrimination of characters necessary for sexual recognition, as well as increase concealment and therefore reduce predation on certain species (Kroger and Gutherie, 1972). Several recent reviews summarize the current knowledge of the effects of turbidity and suspended sediments on aquatic organisms (Morton, 1977; Peddicord and McFarland, 1978; Stern and Stickle, 1978; Guillory, 1982). Based on the results of laboratory studies, investigators often conclude that ecological effects of dredging and associated turbidity are transient and minimal (Stern and Stickle, 1978). Motile organisms have the ability to avoid or vacate areas of excessive turbidities (Guillory, 1982).

The physical and physiological effects of suspended sediments on gill tissue of adult fish has been examined and a variety of conclusions drawn. Fine particles of sediment can coat fish gills and larger particles can impede water flow between gill lamellae (Nikolsky, 1963; Sherk _et al_., 1976). Wallen (1951) found fish exposed to 20,000 ppm of suspended sediments exhibited behavioral responses such as gulping air and floating prior to death. However, examination of gill tissue did not reveal tissue damage, but opercular cavities were clogged with sediment. Such clogging affects circulation, respiration, excretion, and salt balance (Ellis, 1937 and Cordone and Kelly, 1961). However, swimming in sublethal concentrations of suspended solids, as well as secretion of mucous is thought to be effective in clearing of fish gills and permits survival in nature when exposed to such conditions (Wallen, 1951 and Stern and Stickle, 1978).

Sublethal effects of exposure of gill tissue to high concentrations of suspended solids include hematological response to reduced gas exchange at the gill surface and abrasion of gill tissue as well as body epithelium (Sherk _et al_., 1974). However, the properties - physical or chemical - which elicit the response of the fish are uncertain. The number, density, size, shape, and minerology of the particles, as well as presence and form of organic matter, metalic oxide coating, and sorptive properties may be collectively or singularly important (Sherk, 1973). Juvenile fish may be more sensitive to suspended solids due to the often higher metabolic rate of juvenile fish compared to that of adults of the same species, in addition to the smaller size of gill openings (Sherk _et al_., 1975 and Stern and Stickle, 1978). The most tolerant species in laboratory experiments are those whose habitat preference is the mud-water interface where suspended sediment concentrations are normally greater than in the water column (Sherk _et al_., 1975).

The effects of suspended sediments on fish larvae are uncertain. Auld and Schubel (1978) found that survival of yellow perch larvae in the laboratory following 48 to 96 hr exposure to concentrations of suspended sediment greater than 500 mg/L was considerably reduced. However, the

investigators feel that mobility of the larval fish will allow moderate amounts of sediment to be cleaned off provided there are no toxic effects.

Fish, such as bay anchovy, which are visual feeders may be affected by reduced light penetration as a result of increased turbidity; however, prey species may be afforded protection from increased concealment (Wilbur, 1971 and Stern and Stickle, 1978). In Lake Pontchartrain, bay anchovy appear to feed on whatever small invertebrates are abundant (Levine, 1980).

Packing of the gut with large amounts of sediments in fish exposed to large amounts of suspended solids has been reported (Sherk et al., 1974 and Peddicord and McFarland, 1978). This tendency does not appear to be related to the typical feeding behavior of a species, since large amounts were found in small striped bass (50-60 mm) which are not filter or deposit feeders (Peddicord and McFarland, 1978). The effect of such sediments in the gut on continued feeding or food utilization is unknown.

Increased turbidity may interfere with initiation of feeding of fish larvae that require schooling behavior and its perception by visual cues, to stimulate feeding (Shaw 1960, 1961). The period of transition from endogenous to exogenous food sources may be crucial as outlined earlier and may be affected in several ways by the presence of toxic substances. Clogging of guts of juvenile striped bass has been reported (Peddicord and McFarland, 1978) and a similar situation may occur in larval fish. Laboratory rearing experiments have often shown larval fish to select food on the basis of particle size, ingesting appropriate size particles regardless if they are live or dead zooplankton, phytoplankton, or plastic beads. Feeding on non-nutritive particles may satiate the larva physically but not physiologically. Effects may include alteration of activity and food capture behavior, change in internal cell structure and composition during starvation, as well as changes in sinking rates (Rosenthal and Alderdice, 1976). These effects in combination with reduced oxygen concentration may be substantial.

Fish may be attracted to a dredging site if suspension of large numbers of invertebrates are associated with the operation (Viosca, 1958; Stickney, 1973; Guillory, 1982). In Lake Pontchartrain, higher trawl catch rates of gulf menhaden and Atlantic croaker occurred within 200 and 400 ft, respectively, of the dredge than at 1400 ft or baseline (no dredging) stations (Guillory, 1982). Bay anchovy were most abundant at stations 800 ft from the dredge rather than baseline, or closer or farther from the dredge. Although it was not considered a factor by Guillory (1982), avoidance of sampling gear during daylight trawling has been shown to affect catch rates in other systems. Higher catch rates in the turbid waters in the vicinity of dredging may be a function of reduced gear avoidance. Tarbox (1974) reported a negative correlation between capture of Atlantic croaker and turbidity near Marsh Island, Louisiana.

Decreased growth rates may occur if there is a reduction in food availability, or if there are increased metabolic costs due to increased searching time because of decreases in numbers of prey or prey location, and increased respiration in response to environmental factors.

In the vicinity of a dredge, dissolved oxygen concentrations are often markedly lower than ambient water (Morton, 1977 and Johnston, 1981). Low dissolved oxygen concentrations in laboratory experiments have been shown to be a limiting factor for growth of fishes if all other factors are favorable (temperature, food availability, etc.) (Doudoroff and Shumway, 1970). Translation of such data to field conditions is often inappropriate, since any single factor is not thought to be solely responsible for growth in nature however (Saunders, 1963).

Decrease in levels of dissolved oxygen may result in behavioral modifications as well as metabolic or physiological changes in fish larvae (Blaxter, 1969 and Doudoroff and Shumway, 1970). Oxygen uptake, as an indicator of metabolic rate, is influenced by temperature, dissolved oxygen concentration, illumination, and presence of other fish (Fry, 1971). Increased respiration rates to compensate for reduced

oxygen availability may occur, although both increases and decreases have been reported (Pivolnev, 1964 and Doudoroff and Shumway, 1970). Swenson and Matson (1976) found turbidity did not affect survival or growth of lake herring larvae; however, they were more concentrated at the surface in turbid water.

Some general, often qualitative statements, about fish growth in response to turbidity have been made. The direct relationships are most often speculative, however, and are perhaps more an effect of the amount of suspended solids than an optical property of water such as turbidity.

In freshwater systems, growth rates of visual and crepuscular feeders have been negatively correlated with turbidity (El-Zarka, 1959 and Schneider and Leach, 1977).

Effects of turbidity or suspensed sediments on growth rates of common species such as Atlantic croaker, spot, and bay anchovy occurring in the naturally turbid Lake Pontchartrain have not been investigated.

Potential effects of suspended solids on planktonic and nektonic invertebrates are similar to those for fishes including physical abrasion of tissues, clogging of gills, alteration of feeding, swimming, or reproductive success or behavior. Considerably fewer studies on invertebrates exist to support these hypotheses however. Sullivan and Hancock (1977) suggest that suspended sediments may adhere to and flocculate on zooplankton, resulting in tissue damage, increased settling rates and altered respiration and feeding. Sherk *et al*. (1975) hypothesized that quantities of inorganic material along with particulate food would interfere with copepod suspension feeding. In laboratory experiments, the copepod *Eurytemora affinis*, which normally occurs in more turbid estuarine areas, increased pumping rates in the presence of concentrations of suspended solids. In nature, suspended solids may signal presence of food. *Acartia tonsa*, a copepod which occurs in less turbid waters, did not increase pumping rates at low concentrations of suspended solids. Laboratory results cannot always be translated to

field conditions however. Acartia tonsa is the dominant copepod in the naturally turbid Lake Pontchartrain. The marine planktonic copepod, Calanus helgolandius, when exposed to "red mud" (fine grained residue resulting from extracting aluminum from bauxite) displayed reduced ability to molt through larval stages to adult, decreased growth and movement of adults, and lack of ovarian development in females (Paffenhofer, 1972).

No specific studies on effects of suspended sediments on blue crabs have been conducted. It has been suggested that brown shrimp (Penaeus aztecus) may occur in greatest numbers in more turbid areas either due to increased nutritive value of the suspended material or reduced predation (Lassuy, 1983).

Turbid water resulting from shell dredging may afford protection to motile invertebrates in an estuary (Sherk, 1971), and will affect a relatively small portion of the naturally turbid area at any given time. Crabs and shrimp may even be attracted to a dredging site to feed on uprooted invertebrates (Guillory, 1972).

Changes in the benthic communities, particularly mollusks, in Lake Pontchartrain have been reviewed in detail in section 3.5.2.1 of the EIS and previously in this apppendix. Benthic organisms comprise one of the two primary food chains in the lake (Darnell, 1958 and Levine, 1980). It is apparent that changes have occurred in the benthic communities and it is the general consensus of most investigators that the most obvious change has been the reduction in densities of larger R. cuneata (>20 mm) in the open lake. The implications of this change to fishery production is not well understood. Due to their size and thick shells, only few fishery species prey upon the larger Rangia. The only species reported to consume the larger ones in any quantity include the black drum, sheepshead, blue crab, and two predaceous gastropods, the oyster drill and possibly the moon snail (Lasalle and de la Cruz, 1985). In contrast, small Rangia are fed upon by a variety of fishes and invertebrates. Most of these other species prefer Rangia less than 5 mm (Lasalle and de la Cruz, 1985), and clams of this size are still very abundant in the lake.

It appears that the two small hydrobiid gastropods, P. louisianae and T. sphinctostoma, have increased in abundance in the open lake. It is believed that this shift in dominance represents a loss in overall benthic biomass in the lake, since the hydrobiids are very small (2-3 mm). Sikora and Sikora (1982) estimated the biomass of R. cuneata based on Darnell's survey to range from 20-50 g/m2. Estimates of benthic macrofaunal biomass from the Sikora's sampling in 1978-1979 and 1979-1980 was 9.1 g/m2 and 7.9 g/m2, respectively. It is also believed that the presence of these opportunistic hydrobiid gastropods indicates stress in community (Sikora and Sikora, 1981).

Thompson and Fitzhugh (1985) reported on changes in the relative abundance and frequency of occurrence of several species of fishes that utilize the open-lake benthic habitat and/or are heavily dependent upon the benthic food chain in Lake Pontchartrain. These included the spot, sand seatrout, and a variety of flatfish such as the hogchoker, lined sole, southern flounder, and bay whiff. Levine (1980) examined gut contents and investigated the feeding habits of these and other fishes in the lake.

Spot were found to feed on a great diversity of food organisms. Nearly 70 percent of the 197 examined spot consumed bivalves, including Rangia, Congeria, Macoma, and Mulinia, and these bivalves accounted for 27 percent of the total food. Copepods, mostly benthic harpactocoids, comprised over 50 percent of the food. Other organisms, including chironomids, amphipods, isopods, polychaetes, and gastropods were also consumed. Hydrobiid gastropods occurred in about 25 percent of the spot. Sand and other bottom material in the intestinal tracts indicated that spot seem to feed "into" the substrate (Levine, 1980). Darnell (1958) reported that young spot tend to swim in schools and feed just above the bottom. At about 25 mm in length, their oblique mouth becomes inferior, at which time they begin to feed more on the bottom. As they approach maturity they dig more deeply into the bottom, consuming a larger quantity of burrowing organisms.

All of the groups of organisms consumed by spot seemed to remain important in all sizes of spot, except for copepods, which were not utilized by larger spot. However, feeding upon smaller organisms seemed to prevail in spot throughout their size ranges. Station by station comparisons from trawl samples seem to indicate that spot are opportunistic, feeding on whatever benthos is most abundant in the area.

Sand seatrout are known to use the open-lake habitats as nursery areas. Based on Levine's findings, small sand seatrout (< 60 mm) depend heavily on copepods and mysids as a food source. However, with growth, larger fishes seem to prefer macrocrustaceans and fishes. Fishes found in sand seatrout by Levine (1980) included anchovies, ladyfish, silversides, and speckled worm eels. Of these, only the speckled worm eel is associated with the benthic habitat. Mollusks appear to be of little direct use to sand seatrout. Darnell (1958) reported similar feeding habits.

Of the flatfishes noted by Thompson and Fitzhugh (1985) to have declined in abundance and frequency of occurrence, Levine (1980) examined the foods of the hogchoker and southern flounder. Hogchokers are prone to regurgitation when captured by trawl and examination of stomach contents is difficult. In 69 hogchokers with food examined by Levine, a variety of benthic invertebrates, primarily chironomids, were found. About 82 percent of the total food was chironomids. It is believed that this was due to feeding specialization, as hogchokers are known to feed on a variety of small invertebrates. In 3 hogchokers examined by Darnell (1958), amphipods comprised about 50 percent of the diet.

The feeding habits of the southern flounder have been examined by several investigators. It is known to feed primarily on fishes, shrimp, crabs. Darnell (1958) examined 14 flounders. They had consumed bay anchovies, Atlantic croaker, and crabs. Levine (1980) examined four flounders and they had consumed the same fishes found by Darnell.

Based on the available information, it is difficult to determine what factors have caused an apparent decline in abundance and frequency of occurrence of certain fishes in the lake. The above information regarding the feeding habits of four of these fishes does not elucidate the matter. The spot and hogchoker appear to directly depend upon benthic organisms for their food source, but neither feed on large Rangia. The spot feeds on burrowing organisms during certain life stages. The sand seatrout and southern flounder apparently do not feed on organisms directly associated with the sediments and any impacts to their food source as a result of benthic disturbance would be indirect. Mollusks are consumed only rarely by these species.

It is interesting to note that the Atlantic croaker, a species that directly utilizes benthic organisms as a food source, has not demonstrated a noticeable decline in abundance or frequency of occurrence. Thompson and Fitzhugh (1985) reported that the Atlantic croaker remained the second most abundant and frequently collected species throughout the study period. Except for periods influenced by opening of the Bonnet Carre' Spillway, the overall community position of the Atlantic croaker was relatively unchanged. Croakers are generalized feeders with the young consuming zooplankton, microcrustaceans, and small mollusks. Very small croakers depend heavily upon copepods and amphipods. Adults consume annelids, polychaetes, mollusks, decapods, and small fishes. Levine (1980) examined 277 croakers ranging in size from 12-252 mm. There was great diversity in the croaker diets. Most organisms in the food were the same as reported by previous investigators and indicated that feeding by croakers occurs near, on, and in the substrate. However, Chao and Musick (1977) reported in a specific study related to body form that spot feed more "into" the substrate than croaker, thereby creating a niche segregation. It is possible that the great diversity in the feeding habits of croakers is the reason they have not exhibited a noticeable decline.

Based on the available information, it is difficult to determine what has caused the apparent decline of certain fish species in the lake.

Periodic disturbance of the lake bottom by shell dredging has more than likely reduced the abundance of large Rangia and other large bivalves. However, the bulk of the diets of most of the benthic-oriented fishes is comprised of small organisms which are very opportunistic and prolific and are known to repopulate very rapidly.

Certain factors other than shell dredging must also be considered and put into perspective. When evaluating the trends in fisheries noted by Thompson and Fitzhugh (1985), possible differences in sampling techniques must be considered, as they acknowledged. Although their trend analysis relied solely on information from trawl samples, it should be noted that efficient capture of certain bottom-dwelling fishes depends largely on the size and weight of the trawl boards and the manner and angle in which the boards are attached to the trawl. Heavier, properly attached boards dig into the substrate and are more efficient at capturing fishes such as hogchokers, lined sole, bay whiff, and flounders. The cut and configuration of the mouth of the trawl are also a factor. It is likely that the individuals conducting the sampling were familiar with these factors; however, it takes a great deal of experience to rig a trawl properly. Experienced shrimpers are well aware that in order to maximize shrimp catch, particularly browns, that the net must fish into the substrate. Shrimping is another factor which must be considered when assessing the reduction in certain fishes.

The various flatfishes, spot, sand seatrout, Atlantic croaker, and other demersal species are often caught in extremely large numbers and thrown back overboard dead. The impacts of this shrimping by-catch on populations of certain fishes are very controversial. Additional information on the effects of shrimping on Lake Pontchartrain is presented in Section 3.8 of the EIS.

It is known that aquatic systems impacted by contaminants often have stressed fish populations represented by a relatively small number of species. It is believed by some that shell dredging releases

contaminants from the sediments into the water column and eventually into the aquatic food chain. Information concerning contaminants in Lake Pontchartrain and the potential for contaminant-related problems as a result of shell dredging are discussed in section 3.4.2 and Appendix C. As discussed in that section, studies indicate that the areas in the lake with the highest contaminant levels are nearshore, particularly where tributaries and outfall canals enter the lake. Investigations of contaminants in the lake indicate no particular problems in the areas of the lake where shell dredging is permitted. Studies by GSRI (1974) and DEQ (1984) indicate that shell dredging does not release harmful levels of contaminants. Additional information on the effects of sewage and urban and agricultural runoff on Lake Pontchartrain is presented in Section 3.8 of the EIS.

As discussed previously in this EIS, it is believed that there has been a long-term increase in turbidity in the lake and that shell dredging is one of many factors implicated in this increase. Such an increase could reduce primary productivity in the lake which could, in turn, reduce overall fishery productivity. Sikora and Sikora (1982) reported a sharp drop in total organic carbon levels in the sediments based on levels reported by Steinmeyer (1939) and levels from their sampling. Such a drop would indicate a decrease in primary productivity in the lake; however, the method of analysis used by by Steinmayer is not known and it is not known if the total organic carbon levels reported by the two authors are comparable. Unfortunately, no other significant data regarding total organic carbon levels in the sediments is available.

Loss of wetlands surrounding Lake Pontchartrain has also exerted impacts upon the fishery resources of the lake. The adjacent marshes supply an important component of the food web in the form of organic detritus.

Analysis of commercial fishery trends does not reflect any clear declines in harvest of important commercial species. Blue crab landings, the most important component of the lake's harvest, averaged about the

same in recent years as they did for the period 1959-1964. Shrimp landings have been very high in some recent years. Total finfish harvest has increased in recent years, largely due to increased landings of catfish and black drum. It should be acknowledged, however, that the numbers of licenses for the various fisheries have also increased rapidly over the years and it is likely that catch-per-unit-effort has decreased. Unfortunately, data do not exist to document such a decrease. Additionally, factors such as salinity in a given year seem to have marked effects on landings. Shrimp harvest in the lake is very good during years when salinities are elevated, particularly if the spillway was opened in the previous year. On the other hand, shrimping is relatively poor in the lake in the year of a spillway opening. Catfish landings are affected just the opposite, with higher landings in fresher years and vice-versa. Another factor governing landings is marketability of a given species. For example, black drum, which was not a popular species for many years, has recently risen in popularity. Perhaps the most difficult problem in attempting to determine trends from landings data is the fact that as discussed previously, the data are highly inaccurate. This is particularly true in Lake Pontchartrain since it lies in a heavily populated area and much of the harvest is sold directly to restaurants and consumers and is never reported.

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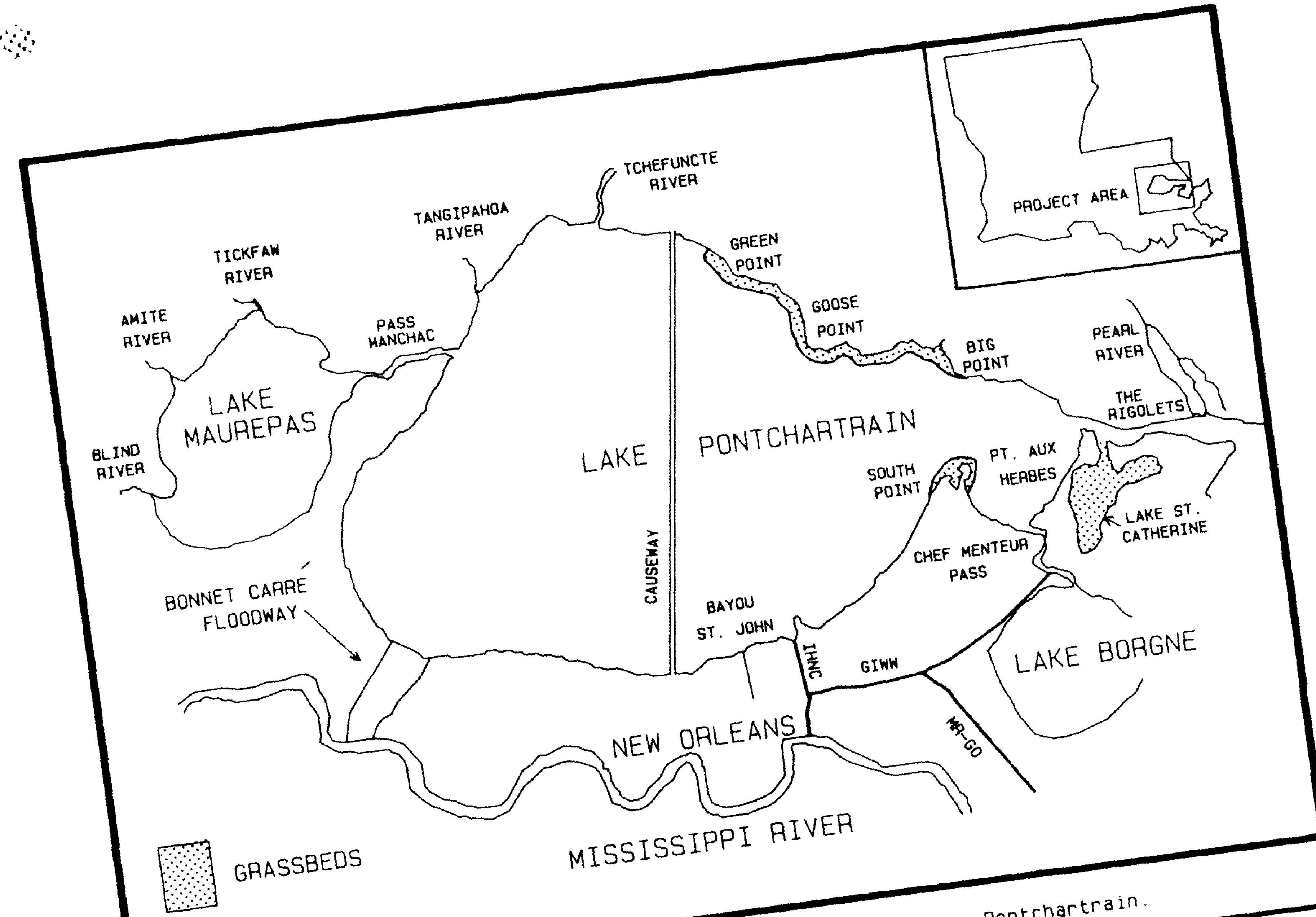

Figure D-1. Primary concentrations of grassbeds in Lake Pontchartrain.

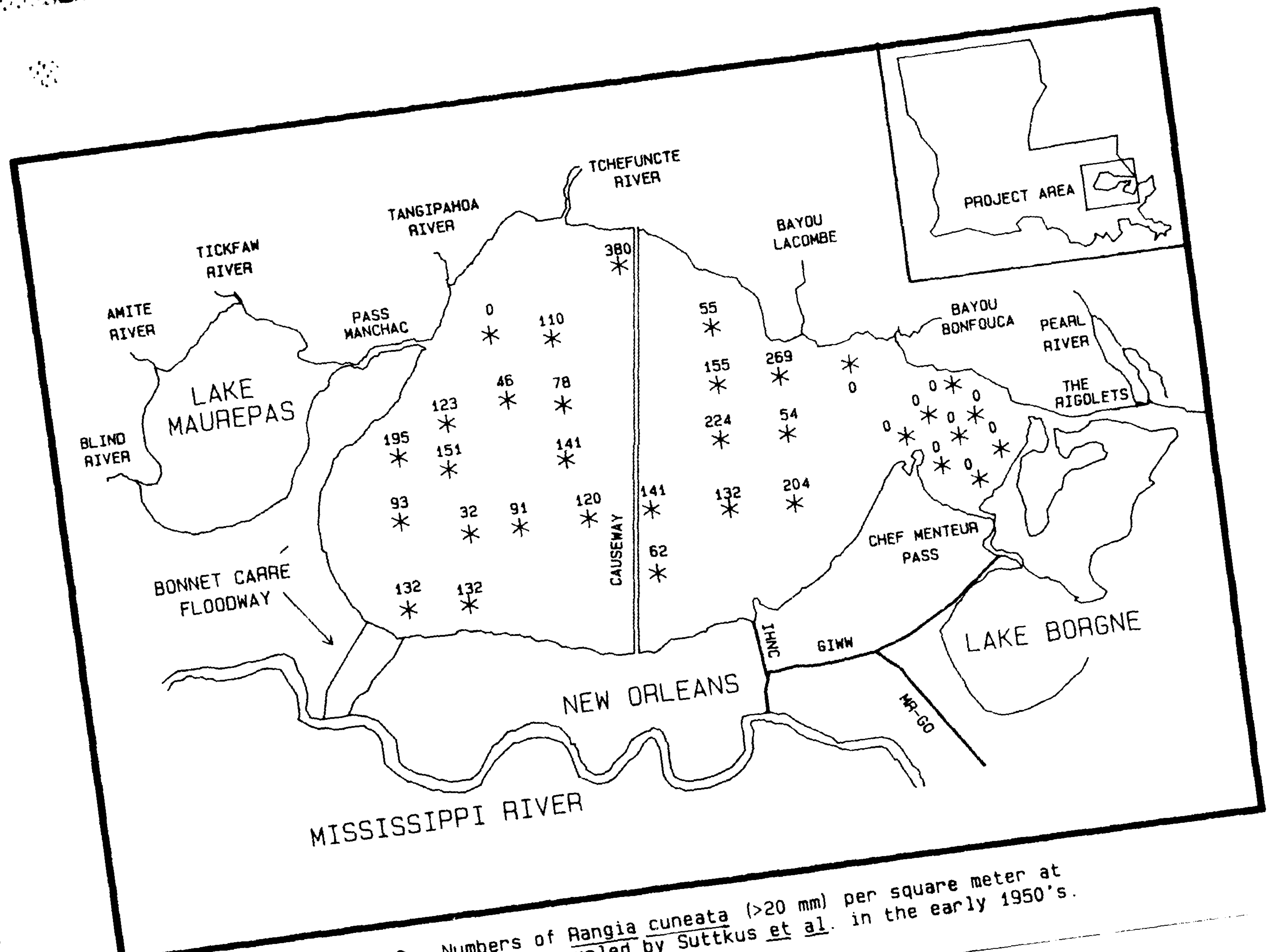

Figure D-2. Numbers of _Rangia cuneata_ (>20 mm) per square meter at stations sampled by Suttkus _et al_. in the early 1950's.

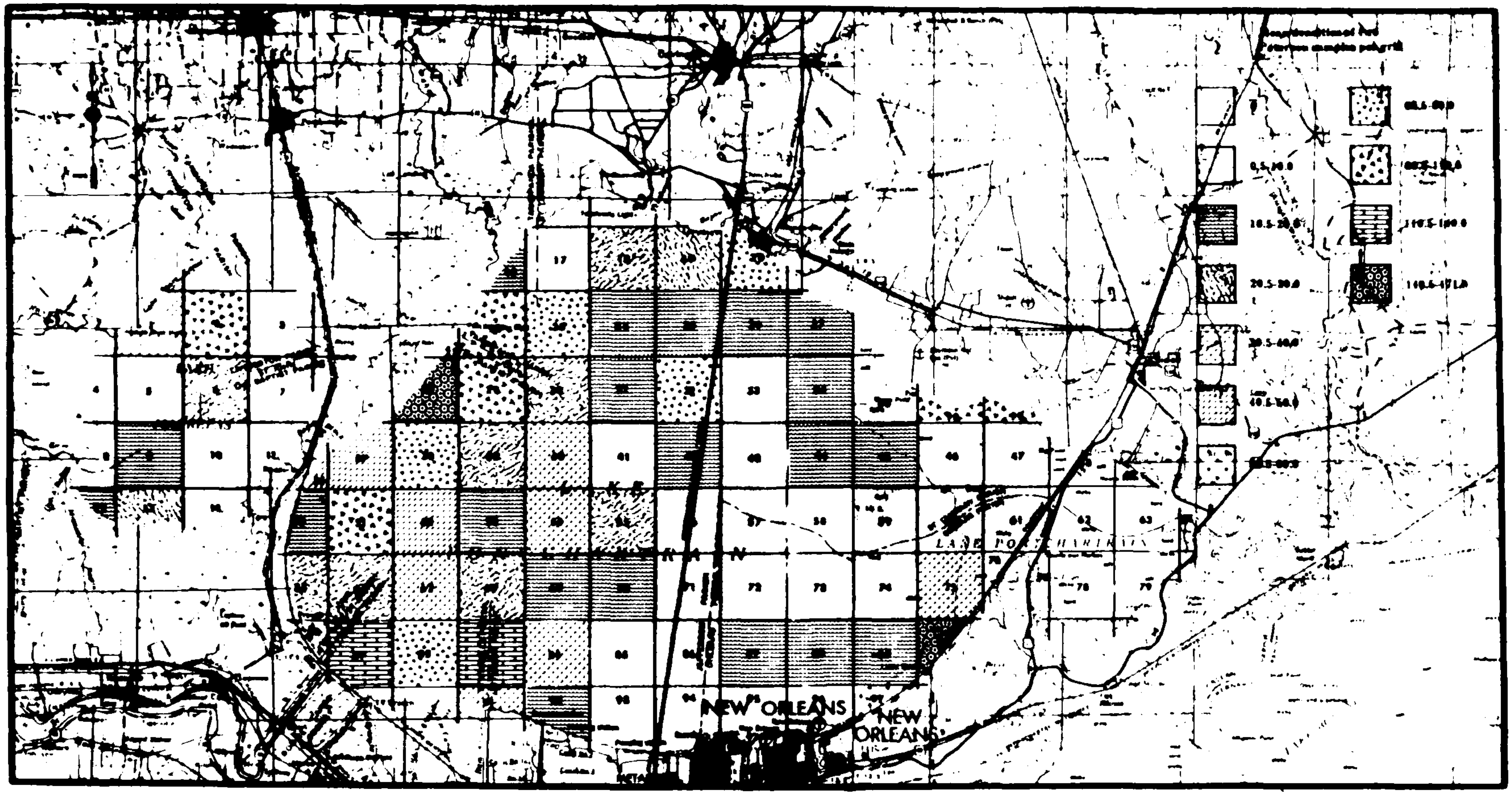

Figure D-3. The 99 grids used by Dugas *et al.* (1974) to sample the molluscan communities of Lakes Pontchartrain and Maurepas.

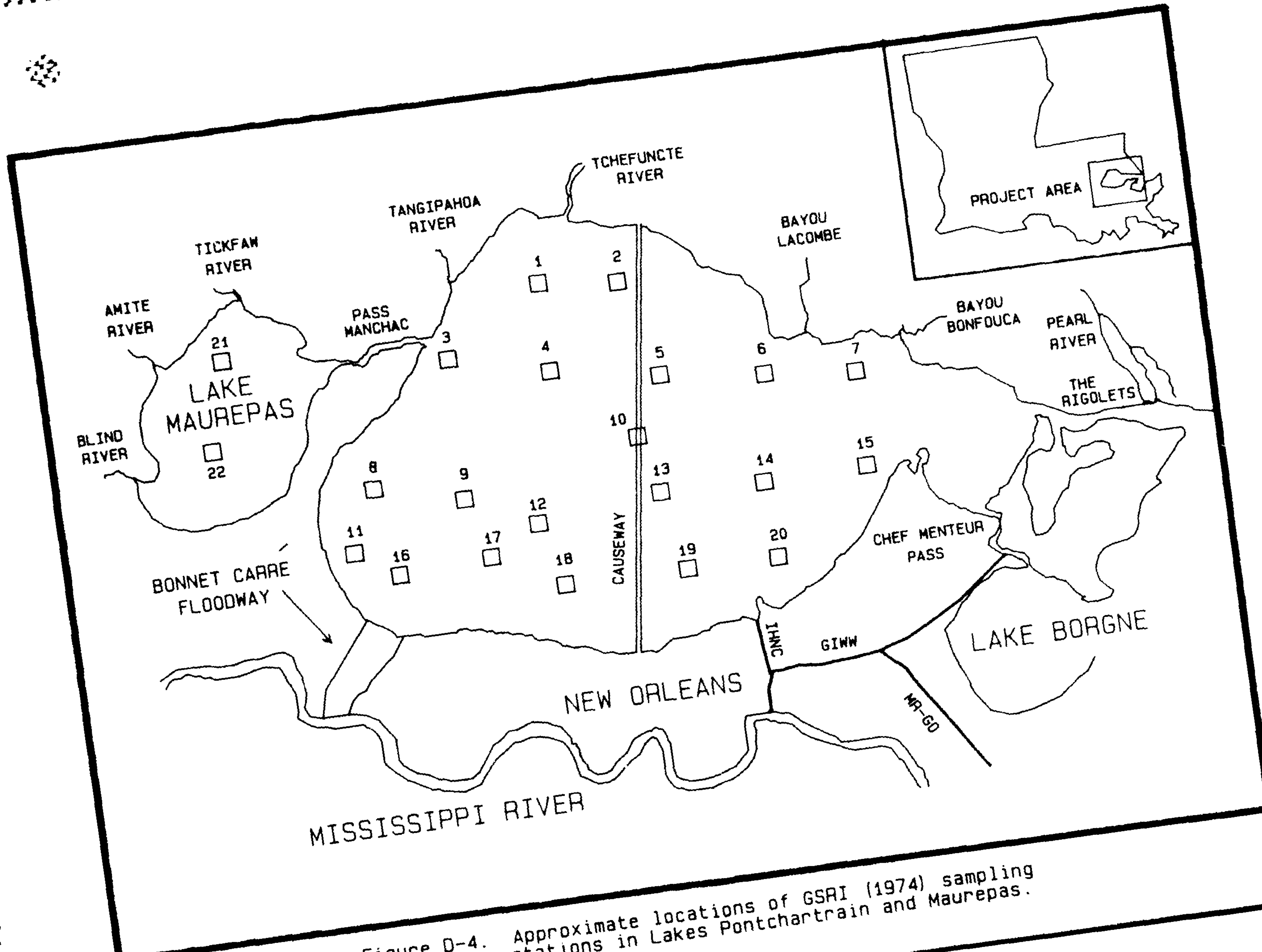

Figure D-4. Approximate locations of GSRI (1974) sampling stations in Lakes Pontchartrain and Maurepas.

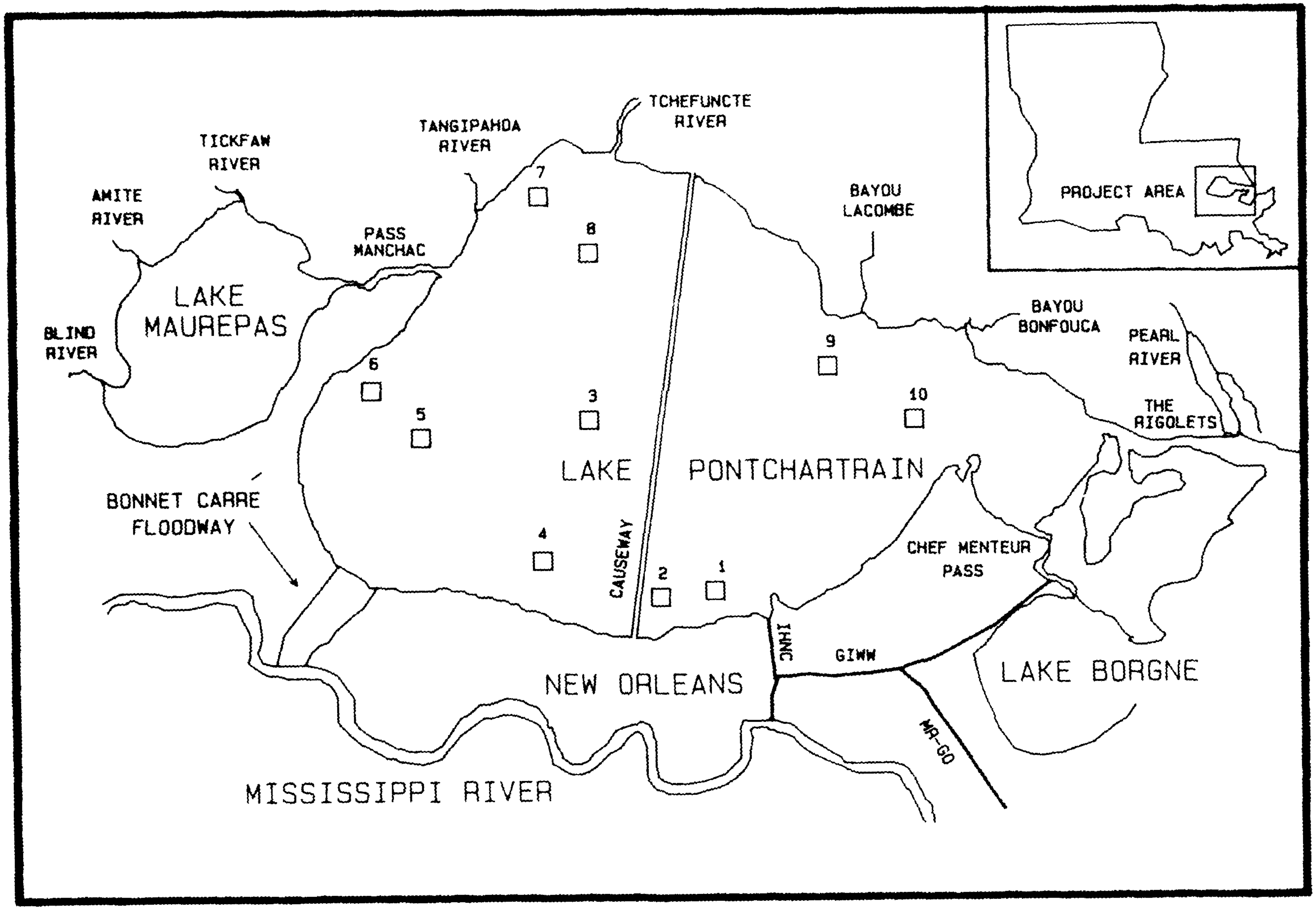

Figure D-5. The 10 stations used by Bahr et al. (1980) to survey macrobenthos in Lake Pontchartrain.

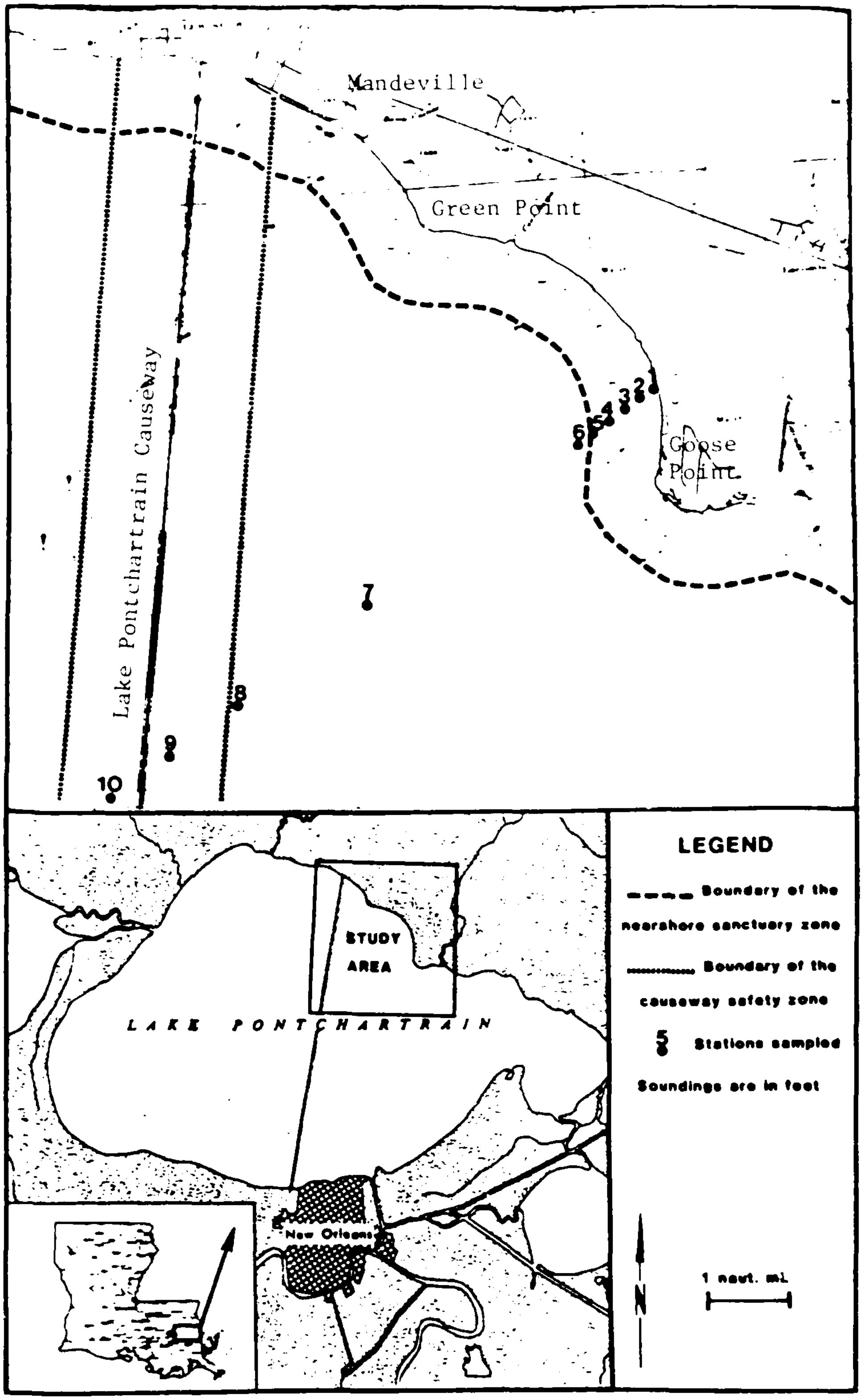

Figure D-6. Transect showing 10 benthic stations sampled by Roberts (1981).

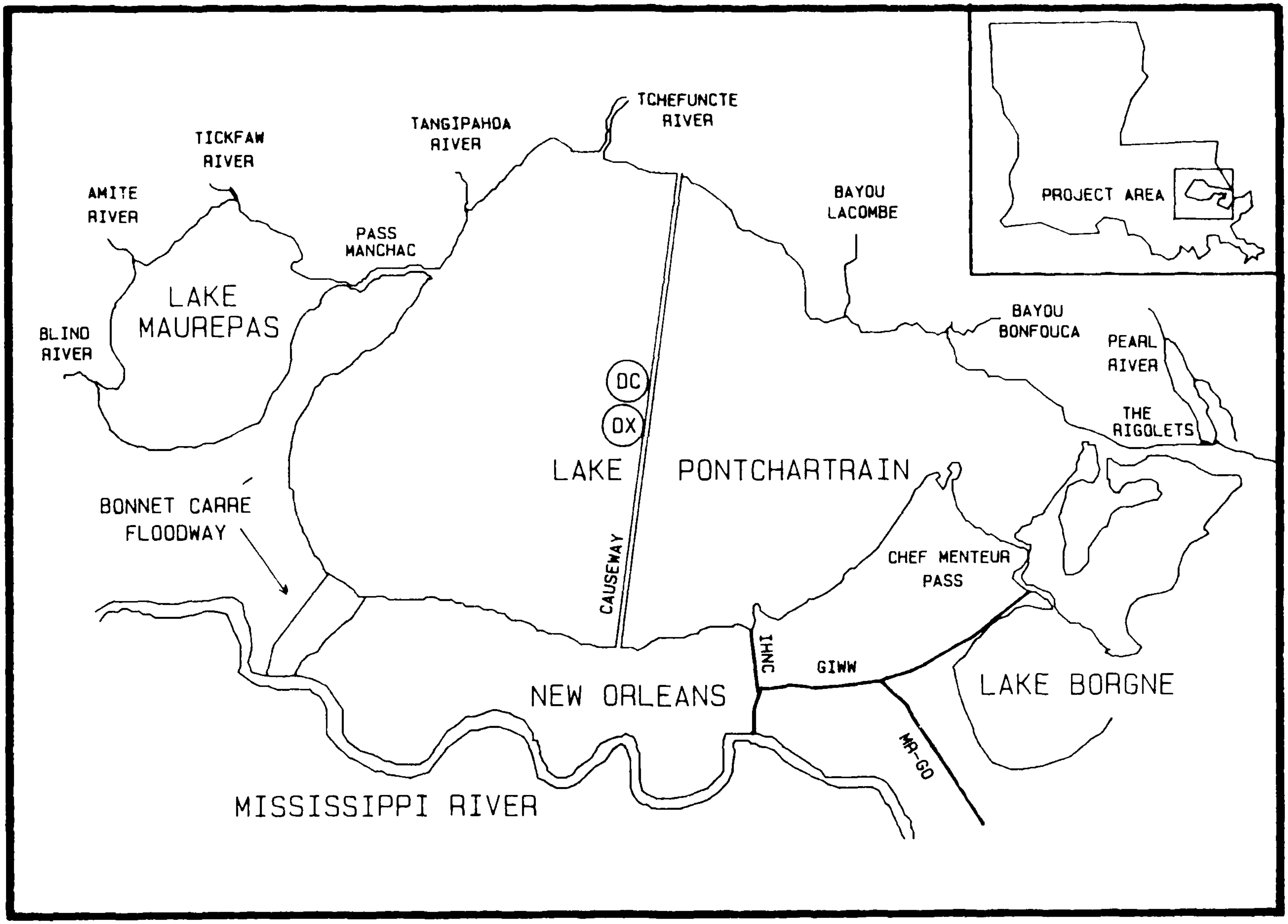

Figure D-7. Experimental dredge station (DX) and control station (DC) used by Sikora et al. (1981).

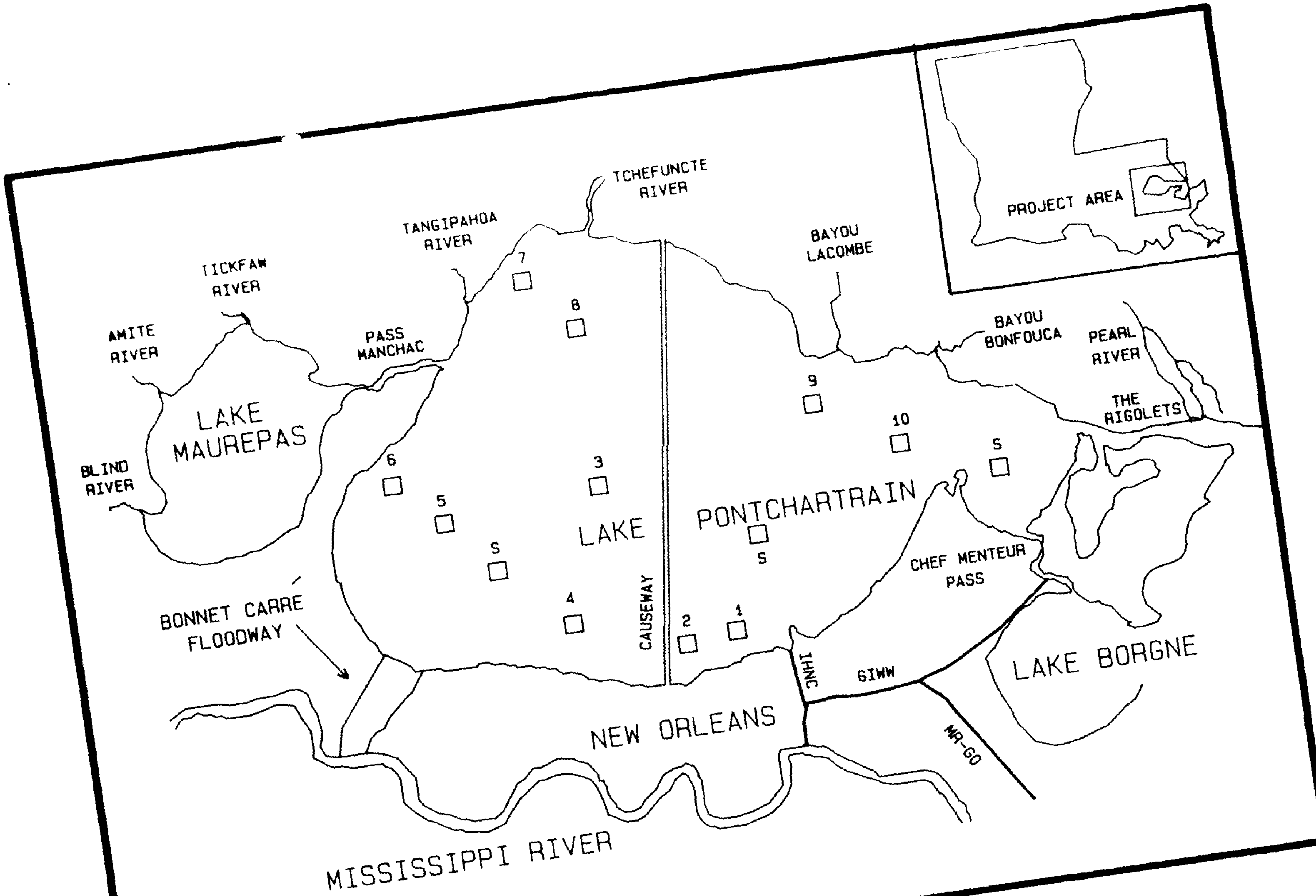

Figure D-8. The ten monthly and three seasonal stations sampled by Sikora and Sikora (1982).

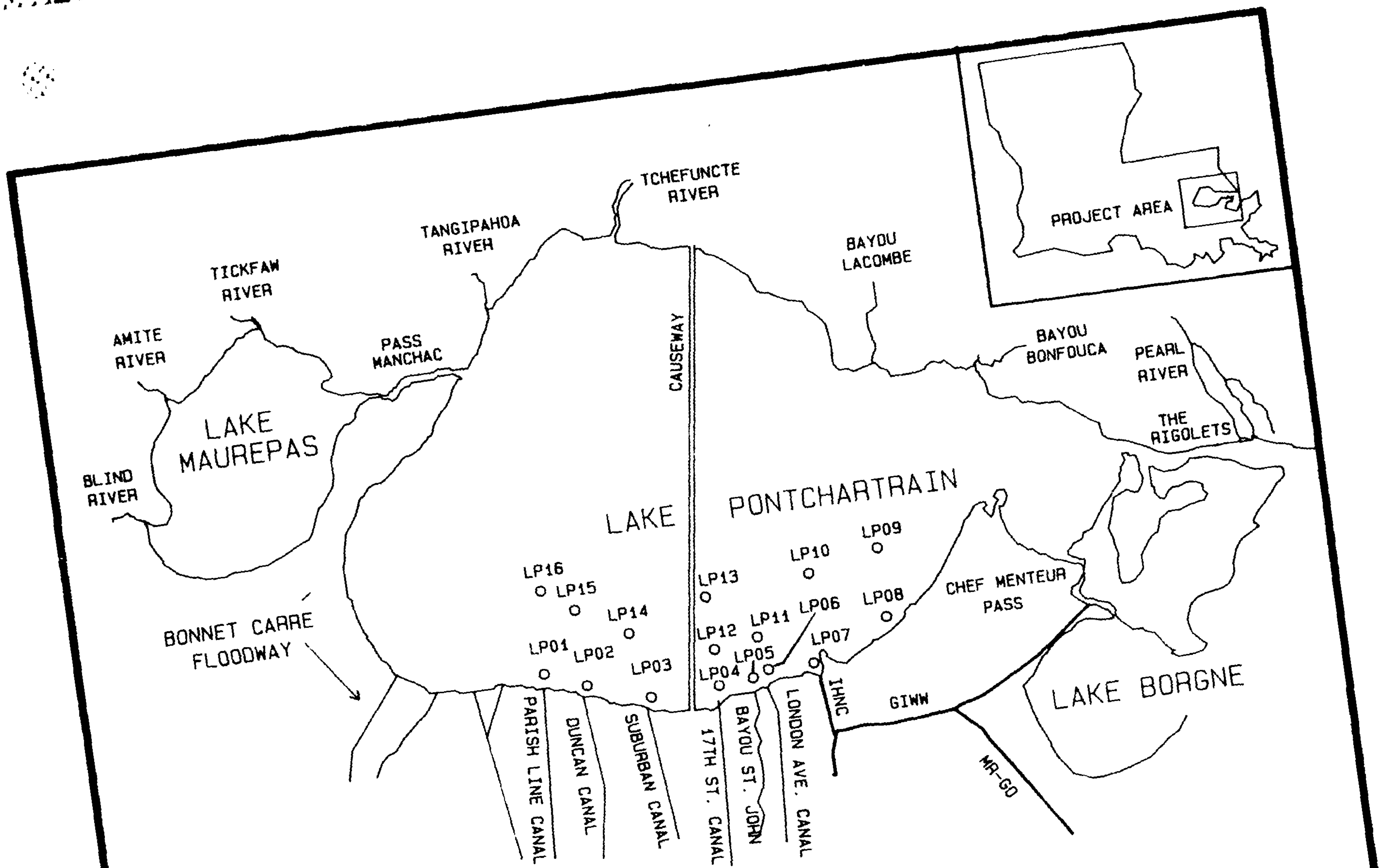

Figure D-9. Locations of the 16 benthic sampling stations used by Poirrier et al. (1984).

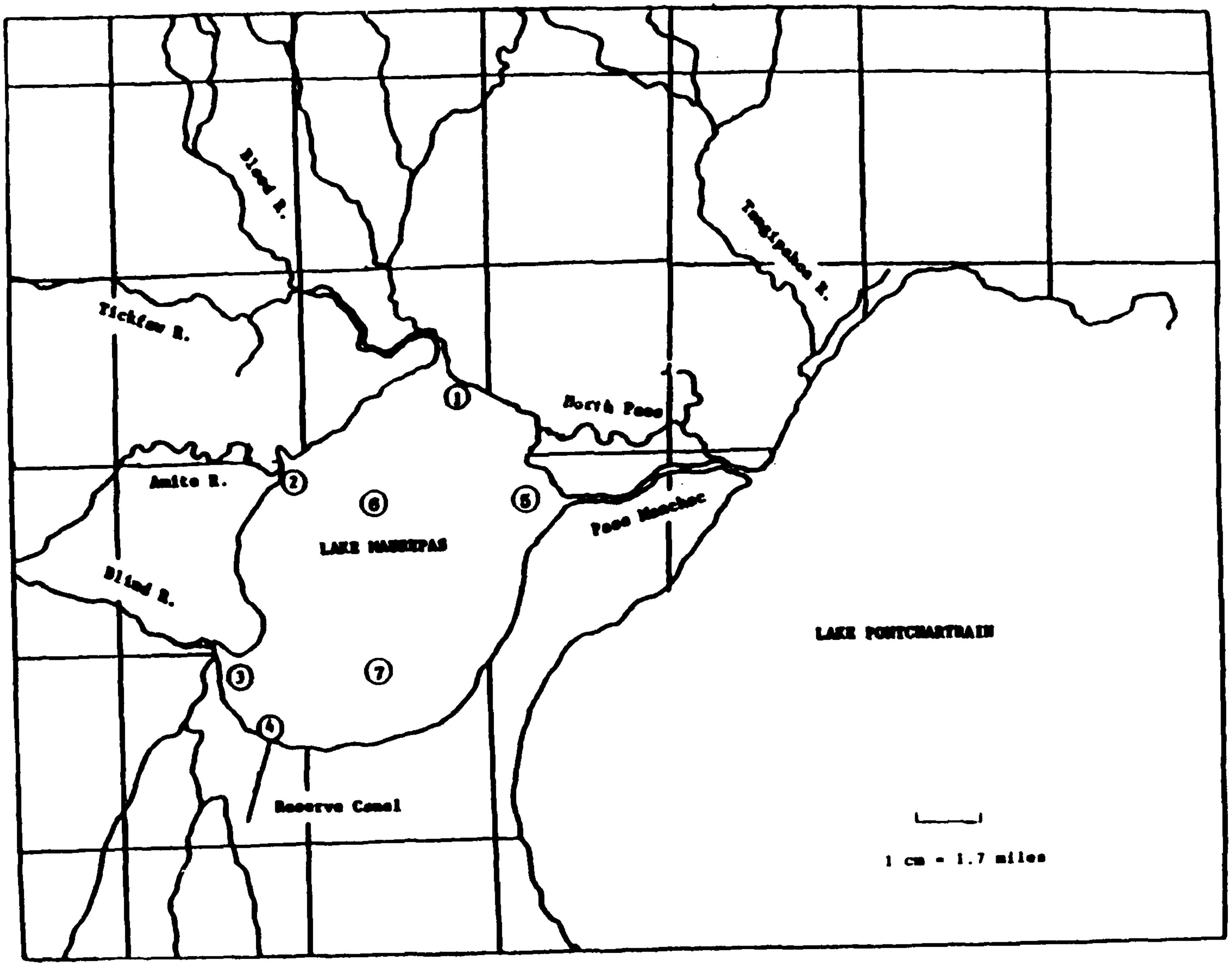

Figure D-10. Locations of the 7 benthic sampling stations used by Childers et al. (1985).

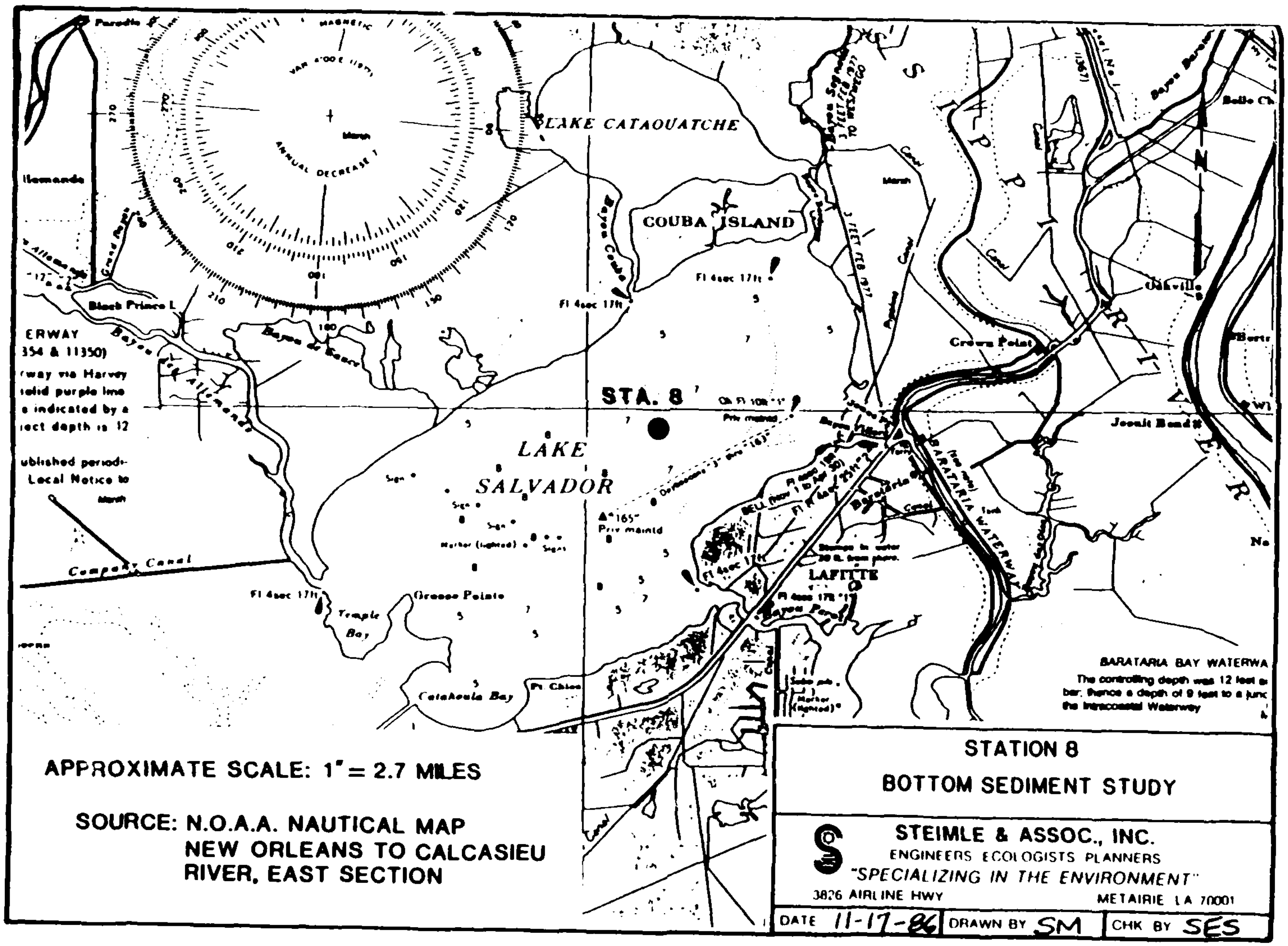

Figure D-11. Station 8 in Lake Salvador where 100 live <u>Rangia</u> were collected for laboratory study.

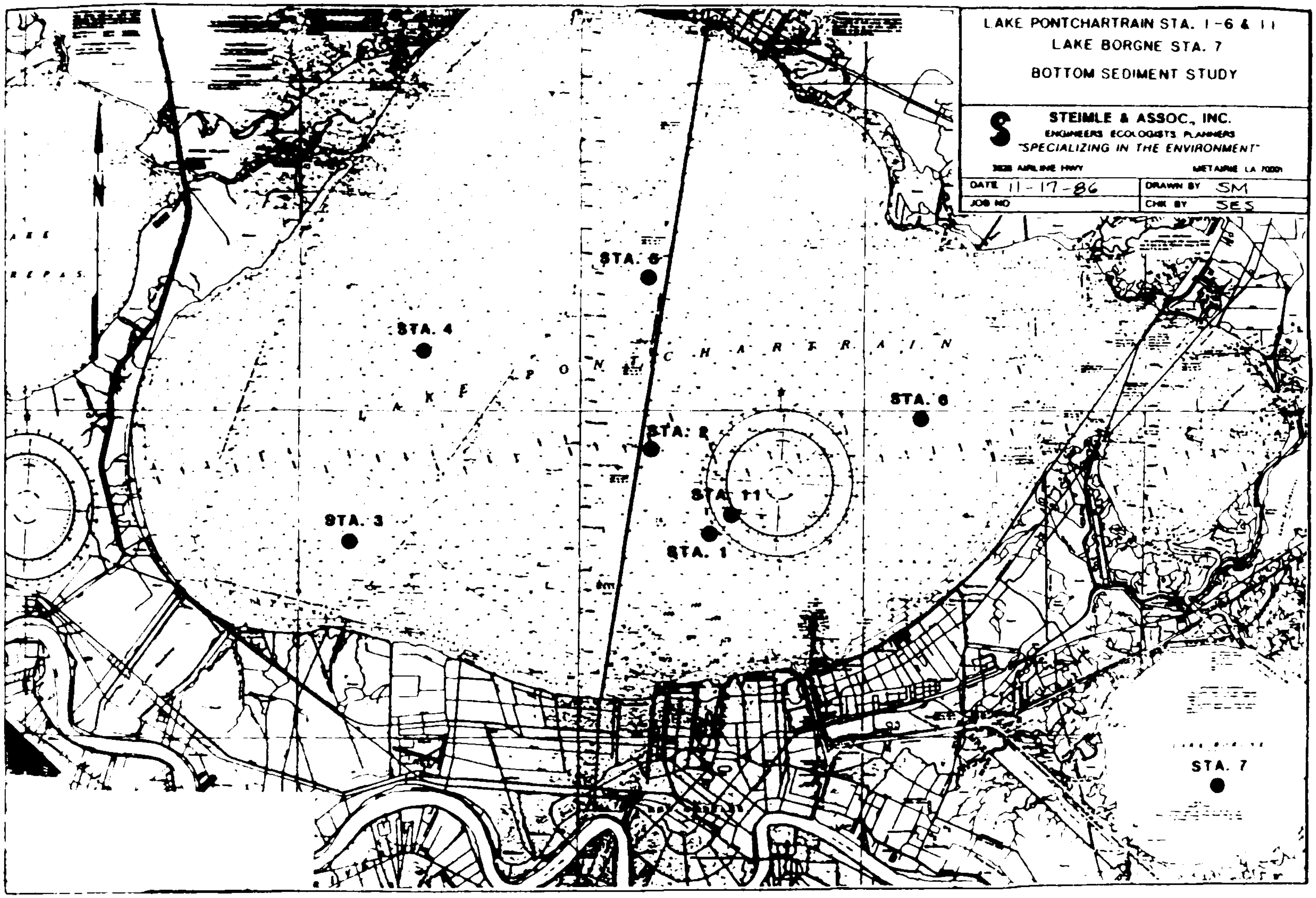

Figure D-12. Location of Station 11 where sediment was collected for laboratory studies with live Rangia.

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